41ST CONGRESS, 3d Session. } HOUSE OF REPRESENTATIVES. { REPORT No. 49.

SENATE CHAMBER AND HALL OF THE HOUSE OF REPRESENTATIVES.

MARCH 3, 1871.—Ordered to be printed and recommitted.

Mr. JENCKES, from the Select Committee on Ventilation, made the following

REPORT.

The Joint Select Committee of the two Houses of Congress appointed at the last session to examine into the present condition of the Senate Chamber and Hall of the House of Representatives as regards lighting, heating, and ventilation, and their acoustic properties, and the defects and disadvantages existing in the same, and the best method of providing remedies therefor, make the following report:

Several committees in previous Congresses have been charged with the same duty as that imposed upon this committee by the joint resolution authorizing their appointment. The reports of these committees contain much useful information, and many theories and speculations concerning the several subjects embraced within the scope of their inquiries. But their investigations, and the elaborate reports which followed them, have led to nothing substantial in the way of improving the condition of the two halls. The evils were felt and admitted, but the plans which were proposed for removing them did not meet the approval of either House. This committee have had the advantage of the labors of all these previous committees, and in conducting their own investigations, and in making experiments to test the accuracy and value of the theories and plans submitted to them, their endeavor has been to arrive at some correct and practical result. Their first effort was to ascertain with as much exactness as possible the existing state of things in the two halls which affected the subjects of their inquiries; then to detect the conditions under which the evils complained of appeared, with a view to the removal of their causes as far as practicable. This mode of conducting their investigations led the committee to the conviction that the magnitude of the evils had been greatly overestimated, and that the problem which had been submitted to this and previous committees was not so difficult of solution when its elements were once discovered and understood.

The remarks which follow will be mainly applicable to the hall of the House of Representatives, as that is much the larger of the two, and the incidents of its use to be inquired into are complicated with much greater difficulties. Whatever is stated about the larger hall may be taken to be true with regard to the smaller, although in a lesser degree, unless otherwise stated.

AS REGARDS THE LIGHTING OF THE HALLS.

The light is received through large plates of glass in the roof, half an inch in thickness, modified and reduced by the stained glass in the ceil-

ing. The supply from other quarters is too limited to be taken into account.

The "defects" in this mode of admitting light are in the too limited space allotted to the glass in the roof, and in the obstruction to the transmission into the hall of that which is thus admitted by the stained glass in the ceiling of the hall. If the light passed freely through this ceiling the area of the glass in the roof would probably be sufficient. But the most translucent parts of this stained glass absorb or keep back at least twenty-five per cent. of the light which strikes their upper surface, and the stained portions, which are more than one-half of the area of the ceiling, intercept at least fifty per cent. (See letter of Professor Henry.)

The "disadvantages" of this mode of lighting the hall are that no clear light is admitted from without at its full illuminating power into any part of the hall; and that in order to relieve the eye from the effect of the direct rays of the sun upon this semi-transparent ceiling it became necessary to use large blinds, or louvers, which, while they shaded the ceiling from the sun, greatly obstructed and diminished the force of the light which passed through the glass in the roof. Besides, the committee found these louvers constructed in sections, disconnected, and only to be adjusted by an attendant who could reach the point from which the sections could be moved by walking along a narrow plank causeway laid across the large iron girders of the ceiling. The consequence was that there was no uniform adjustment of the sections, and that some would be closed too much in cloudy days, when none too much light could be admitted if all of them were wide open. The eyes of those on the floor would be sorely tried in the obscurity. To the changes in the force of the light caused by the clouds were added the variations and uncertainties in the management of these louvers.

This method of lighting the hall was not in the original design of the architect of these buildings. His plan was to have raised the inner walls next to the hall to a height to have admitted windows of sufficient capacity for lighting the hall in all states of the sky and weather. On the northern side of the hall a clear and unobstructed light would have been admitted at all times, while on the other sides blinds would have been adjusted so as to exclude the direct rays of the sun without creating obscurity in the hall below. These windows were designed to be double, so as to have afforded protection against the cold in winter and sudden changes at all seasons. By this arrangement the hall would have received an abundance of cheerful light, sufficient at all times, of easy control under external changes, and grateful to the eyes of those sitting at their desks on the floor.

Former committees have considered the propriety of reconstructing the roof in conformity with the original design of the architect, and have caused estimates to be made of the expense of such reconstruction. This committee have to some extent verified the estimates of the expense, and find it so great that they do not concur in the views of a former joint committee, who recommend the change to the original plan. These estimates at present prices of labor and materials would make the cost of the alterations about $200,000 for each of the two wings. Nor would it be safe to calculate that the work, if undertaken, could be finished between the sessions of Congress.

Some changes have been recommended by the committee and have been made under the direction of the architect of the capitol. One of these was, to connect the louvers or blinds under the sky-light so that all under each slope of the roof could be moved and adjusted at the same time, thus rendering it easy for the attendant to admit the full force of

the light or to prevent the rays of the sun from entering the hall, or otherwise to adjust the blinds so as to equalize the light under all external changes. Another change has been made in removing the plates of iron from the row of panels next to the outer squares of glass in the ceiling of the hall and to insert in their place plates of glass. The illumination of the hall is thus increased to some extent in the day-time, and very greatly in the night by placing a circle of gas-burners above each plate of glass. The effects of this change is perceived with more effect in the galleries than upon the floor. In the night, by gas light, every part of the hall is now thoroughly illuminated.

The expense of these changes has not been great, and has been fully provided for by the appropriation of the last session. The lighting of the hall would be still further improved by taking out the stained glass in the ceiling and replacing it by glass ground upon one surface like that introduced into the outer row of panels. A further improvement in the light could be made by removing the large plates of glass in the roof which are thick and but semi-transparent, and replacing them with lights similar to those in the roof of the old hall and over the Supreme Court room. Glass thus arranged would not only admit more light, but cause it to be diffused more evenly over the ceiling, and relieve the galleries from the shade now cast upon them. But as no complaints have been made of an insufficiency of light since the alterations already described, the committee have not thought it best to recommend an increased expenditure for that purpose. They are satisfied that no great improvement can be made in the method of lighting of the hall unless a complete change is made in the structure of the roof. No alterations have been found necessary in the mode of lighting the chamber of the Senate.

OF THE MODE OF HEATING THE HALL.

Whenever it becomes necessary for the comfort of the occupants of the hall to increase its temperature above that of the external atmosphere, steam is let into the coils of pipe in the aperture through which the air is forced into the hall by means of revolving fans, and it becomes heated to the requisite degree by contact with the pipes containing the steam. The air thus heated is distributed by large conduction pipes to different parts of the floor of the hall, through which it is admitted into the hall by means of registers. Some heated air is also forced into the hall through apertures on its sides, at a short distance above the floor.

Whether this mode of heating has "defects and disadvantages" which render it less economical or effective than other systems, the committee did not stop to inquire, as the cost of removing the present apparatus and substituting a new one constructed on any other principle, or acting through other means, would be greater than the committee would recommend or Congress be willing to expend.

The principal defect in the mode now in use is in the manner in which the heated air is conducted into the hall and distributed by means of pipes, flues, and registers. In the present arrangement of the air shaft, pipes, and registers, the heated air is discharged into the hall more freely from openings near the shaft than from those more distant from the source of supply. The Architect of the Capitol has devised a plan which the committee have recommended, by means of which the heated air will be more evenly distributed in its delivery into the hall, and the space beneath the floor is utilized as a reservoir of heated air. This change will also make a great improvement in the construction and

appearance of the floor itself. Substantially the same improvements have heretofore been made in the floor of the Senate chamber, and in the location of the pipes, flues, and registers under and through it.

The greatest obstacle to the preservation of a uniform temperature in the hall was found in the very defective construction of the roof. Taken as a whole, this was little better than an awning spread over the iron rafters. The original plan of this part of the structure having been abandoned, the substitute for it seems to have been adopted without regard to its fitness or permanence, and to have been allowed to remain practically unfinished. The area of that portion directly over the hall is about 13,000 square feet, and of the whole roof, upward of 17,000 feet. Of this area, the plates of glass occupy about 4,000 square feet, in a long parallelogram, divided into equal parts lengthwise by the ridge of the roof. The remaining portion is constructed of sheets of copper three-sixteenths of an inch in thickness, corrugated and fitting loosely together at the joints. The expansion and contraction of this great area of metal has loosened the connection of the plates and opened fissures of considerable width for nearly the whole slope of the roof. The extent of the overlapping of the sheets has prevented leakage during rains, but streams of cold air have free admission. The effect of this condition of the roof has been to cause, in cold weather, the currents of warm air which rise up to it through the ceiling of the hall to become suddenly chilled, and, instead of escaping through the apertures in the roof designed for ventilation, to descend rapidly in a cold shower so as to form in the outer portions of the hall currents which were felt in their downward flow even to the floor. This was the origin of those peculiar chills which would cause members to look up to see if the doors between the galleries and the corridors had not been left open, or to look around and inquire for the apertures through which such a volume of cold air could be so suddenly admitted. These chills were the fruitful source of colds, rheumatic pains, and other serious diseases. Hardly any one escaped their effects. In a cold day in winter, when the temperature kept with difficulty at a comfortable equilibrium by working the heating apparatus so as to counterbalance the refrigerating effects of the roof, the sudden diminution or entire shutting off of the steam in the coils, or even the departure of a considerable number of spectators from the galleries, would diminish the supply of heat and cause the refrigeration to obtain the mastery, to the great discomfort of those who sat beneath the descending currents of the chilled atmosphere. Almost every one has observed this, and many have received injurious effects from it. The reports of previous committees, and of the Architect of the Capitol, had failed to excite sufficient attention to this serious defect in the roof to lead to the making of a sufficient appropriation to provide a remedy for it. As soon as this committee had entered upon its work they became satisfied that this evil should be remedied, if nothing else was done, and upon their recommendation a sufficient sum was appropriated during the last session to provide a substantial fire-proof ceiling immediately below and a few inches distant from the copper roof. The effect of this has been even greater than your committee anticipated. The sudden chills from the cause described have not been felt during the present session, although there has been more severe cold weather and more sudden and extensive changes than for several previous seasons, and the hall has been kept at a comfortable and equable temperature with less use and management of the heating apparatus than before. After the members have taken their seats until the time of adjournment, from about half-past

12 till about half-past 4, the thermometers in the hall have rarely indicated changes of three degrees. The temperature in all parts of the hall occupied for seats has been nearly the same, seldom varying more than a fraction of a degree. On several days when the temperature of the external atmosphere has been upward of 55°, the steam has been shut off from the coils after the session of the House has commenced, and on some such days the temperature in the hall has been the highest of any days during the session. The attendant engineers have rarely allowed the temperature to reach 70° while the heat was dependent upon the supply from this apparatus, but on the days like those referred to, when the steam was shut off, and the supply of heat was not within their control, the thermometers have indicated as high as 71° or 72°. The temperature of the hall during the hours of the sessions of the House has generally been from 66° to 69°, and without any sudden variations.

Some increase of the heating apparatus has been made by introducing grates and coal fires in the cloak rooms. These have been found to be a great convenience and comfort, but their effect has been more decidedly marked upon the ventilation.

The committee recommend the extension of the ceiling of plaster beneath the whole of the copper roof. The air chamber formed between the copper and the plastering is of sufficient dimensions to conduct the currents of cold air which are formed in winter by contact with the copper, as before described, down to the scuppers under the eaves, through which they are discharged without entering the hall; and the currents of hot air formed by such contact in summer are carried up toward the orifices near the ridge of the roof, through which they escape in like manner. The body of air in the chambers forms of itself a shield against both the external cold of winter and the heat from the rays of the sun in summer, and thus aids in preserving the equilibrium of the temperature in the hall.

OF THE VENTILATION OF THE HALL.

The principle upon which all the contrivances for the ventilation of the halls were constructed, and the apparatus fitted and operated, was that of renewing the air which had become foul by respiration and exhalation, by forcing in a continuous supply of fresh air from the external atmosphere by artificial means. It was believed that the air in the hall would be heated while it was being contaminated, and would rise and flow out of apertures in the roof while its place was being supplied by the pure air from beneath. Thus apertures of the area of about 250 square feet were left in the roof for the escape of the foul, heated air as it would ascend from the hall, and a foul-air flue of 25 square feet area, leading downward from the space above the ceiling, was also provided for the drawing off of such foul air either by a connection with the flue of the chimney or by other artificial means. The supply of fresh air was provided for by an air duct leading into each hall, in which was placed a fan operated by a steam-engine, which could create a current sufficient to cause from 50,000 to 100,000 cubic feet of air to flow into the hall every minute. In actual use the supply to the hall of the House is about 60,000 cubic feet each minute, and about half that amount in the Senate. If the air were simply heated in its passage through the hall, or if the heat which it acquired would be sufficient to cause it to rise in one continuous flow, notwithstanding the contamination it receives from various sources at the same time, then the theory would have been

perfectly correct, and the hall of the House would have been the best-ventilated room in the world. The contents of the hall would have been discharged and the hall refilled with pure air once in about seven and a half minutes, without any currents that would have been perceptible and without causing any sensations either of undue dryness, warmth, or chilliness. Indeed, in the ordinary use of the hall in the seasons of winter and spring, when the temperature of the external atmosphere is not above 75° or below 45°, and the hall is occupied only by the members in attendance and the officers of the House, with few spectators in the gallery, there is probably no hall approaching its size in the world which has equally good ventilation. But the designers of this plan of ventilation left out of consideration many of the disturbing elements which make their appearance in the hall in the course of its use, and did not make sufficient allowance for the strength of the resistance of those obstacles which they knew they must meet and overcome. The hall, with from three to five hundred persons upon the floor and in the cloak rooms and from fifteen to twenty-five hundred persons in the galleries and upper corridors presents a very different and far more difficult problem for the science of ventilation than under the conditions first referred to. And when we remember that this extreme occupation may take place in all conditions of the temperature of the external atmosphere, from near zero to upward of 90°; when the air is surcharged with moisture, as well as when it is dry, bracing and electric; when the weather is cloudy, close, and oppressive, as well as when it is clear; when it is calm, as well as when it is windy; in the night, when all the gas-burners are lighted, as well as in the day time, we see that the problem of successful ventilation is complicated with elements not within the scope of the simple plan at first adopted. Hence we are not surprised at finding so many conflicting statements and conclusions in the reports of former committees and of consulting engineers, and at the variety and even oddity of some of the propositions submitted to the committee for the remedy of the actual and imaginary difficulties which exist or were supposed to exist under the present system.

The committee first endeavored to ascertain the existing "defects and disadvantages" in the contrivances for ventilation, before considering any proposition for relief. By so doing, they found, or believed that they found, remedies for most of the more serious evils, without condemning entirely the present system, or recommending any of the new theories urged upon their consideration.

One of the defects in the original plan, and perhaps the most serious one of all, was the theory that the air in the hall which had become foul by respiration and exhalation would rise and flow off in a regular or gradually accelerated current, and that its place would be as regularly supplied from beneath by the pure air forced in by the fans. If the hall had been very long and very narrow, and the fresh air had been forced in at or near one of the ends, or if the area of the floor had been small and the hall had been very high, an approximation to such a result might have been reasonably anticipated. But the hall is nearly four and a half times as long, and three times as broad as it is high, and the fresh air is not all admitted at one place, or on one line across the floor, or at a great number of points arranged regularly throughout the whole area of the floor, so as to apply a continuous force toward ejecting the foul air; but the registers are scattered about the hall widely distant from each other, or are coincident with the sides of the hall. Nor were the apertures in the ceiling or in the roof so situated as to favor the operation of this theory of a continuous flow. Those in the roof were

near the ridge, those in the ceiling were in the outermost row of squares, while the glass ceiling and the surrounding row of squares with iron panels were entirely closed to the passage of air in either direction. The currents of air that escaped through the apertures of the roof were brought in direct contact with the copper.

The greater portion of the seats are directly under the glass in the ceiling.

The copper roof would in cloudy weather and in the night be of about the same temperature as the external air, and if that was below 70°, the usual temperature of the hall, the upward current would be chilled and consequently checked on coming in contact with it, and when cooled would form a downward current, which would seek ingress into the hall through some of these side apertures in the ceiling. Hence arose the phenomenon which has been remarked upon by all former committees and observers, that in cold weather while an upward current could be detected on one side or at one end of the hall in front of the galleries, a downward current would also be manifest on the other. These currents have been at times so strong as to show a difference in temperature of 5° at the same level on opposite sides of the Senate chamber. The foul air which ascended from the occupied portion of the hall to the glass ceiling would also be checked in its flow, and either descend or remain nearly stationary immediately under that portion of the ceiling, and above and around members in their seats. Thus a body of foul air would be formed in the center of the hall, which, under the conditions described, would increase in offensiveness as long as these conditions continued. The effect of this was graphically described by a chairman of a former committee (Mr. COVODE) in a short speech, when the subject of ventilation was brought before the House by this committee, and is set out more in detail in a report made by him from his committee. (H. R. Report No. 65, Fortieth Congress second session). When the air in this central part of the hall once becomes foul, the pure air injected through the registers does not mingle readily with it, or displace it, but passes around it near the sides of the hall to the openings in the ceiling, or through it in ascending streams, mixing with it but slightly. Every one has observed how long streams of pure and muddy water will keep distinct after uniting and flowing in a single channel. When the bottom of a spring is disturbed and a portion of the water is discolored by the mud, the pure water that arises from the sources does not mix at once with the muddy water, or push it through the outlet, but flows under and around it and runs off freely by itself, and often the clear water, to the amount of many times the contents of the spring, thus runs off, before the whole of the muddy water is displaced. There are some lakes which are traversed by rivers whose streams pass entirely through the body of the lake without mingling with its waters, and whose channels are nearly as marked and distinct from the water they pass through at the place of exit as at the place of entrance. So the foul atmosphere in the hall is like the muddy water in the spring, or the sluggish water of the lake, except that the cause of the disturbance is continuing and increasing all the time, and the fresh air from the registers is like the pure water from its sources, struggling constantly with the foul, and escaping by evading it altogether, or carrying it off by little and little. A delicate anemometer plainly discloses these different currents in different parts of the hall, and in some places very near to each other.

The great fact has been patent to every one who has spent any considerable time in the hall, that the body of 60,000 cubic feet of pure air, which is forced into the hall every minute, ascends and escapes

without carrying with it any considerable portion of the carbonic acid gas and other impurities with which the hall is constantly being filled.

The location of the registers causes another serious defect in the ventilation. The principal of these are horizontal, in some cases extending across an entire passage way, and otherwise scattered around between the desks and under the feet of members. They unavoidably become the receptacles of dirt and scraps, and at the close of each daily session, when the fans are stopped and the current of air caused by them ceases, and the sweeping of the carpets commences, they receive a considerable portion of the dirt that is swept over and around them. This dust, when the fans are again started, is driven out into the hall, and sometimes is so dense as to become visible. This causes the irritation of the throat, and the coughings which are heard so frequently in the hall, and which afflict many who are not subject to colds.

Another defect exists in the absence of means to furnish moisture to the air in cold weather. This defect your committee believe to have been very much exaggerated in previous reports, but it is a serious one during the season of very cold weather. For all that period during which the air is driven into the halls without being heated, or being heated but slightly, there is very little difference between the relative humidity of the air within and without the halls. But when the temperature of the external atmosphere is 40°, and below, and is raised in its passage into the halls to between 65° and 70°, the difference of moisture in the heated air becomes apparent, and produces disagreeable effects. The air rapidly supplies itself with a portion of the moisture which it is capable of holding at the increased temperature from the respirations and exhalations, and having been thus loaded with impurities it becomes the more difficult to be purified or displaced by the fresh dry air which follows, as already explained.

There are also some disturbing elements which occasionally derange the existing plan of ventilation, and which are not met or provided for by any of the contrivances now in use. One of these is the effect of the sun's rays upon the metal in the roof. The whole of this structure above the walls, except those portions occupied by the glass plates, is of copper and iron, and those portions which are below the roof, including the large iron beams, are often heated to a very high degree in the hot, clear days of summer. The thermometer has not unfrequently, on such days, when placed in the space above the ceiling and below the roof, indicated a temperature above 140°. This increase of heat above the ceiling ought to improve the ventilation of the hall on such days, and usually does, except when the unequal currents already explained are set in motion, and in such case it is no unusual thing for this heated atmosphere to be drawn down upon one side or the other of the hall, to the great discomfort of those whom it strikes. The same thing occurs when the gas has been burning for some length of time. The discomfort in this case is much greater, as the heated air which is drawn down is charged with carbonic acid gas, the product of combustion.

Another disturbing element is the great variation in the number of persons occupying the floor and the galleries; each one adds to the carbonic acid by his respiration, and to the general discomfort by increased heat and exhalations. The apertures in the roof are large enough, when the fans are in operation, to meet the wants of fifteen hundred people within the walls of the hall, but there is no adequate provision for the necessities of a greater number. The consequence is that when the galleries are well filled the discomfort must increase until a large portion of the spectators leave.

The cloak rooms have also been an obstruction to healthy ventilation. Being kept closed externally, and resorted to by smokers, the air in them became close and saturated with tobacco smoke, which had no place of escape except into the hall.

Some remedies have been applied and others are now recommended, which, it is believed, will partially overcome these defects. There are defects in construction which cannot altogether be overcome without remodeling the whole structure. The committee have not seen their way clear to recommend the adoption of any new plan of ventilation which is based upon entirely different theories, and which would be revolutionary in its effect upon the building. The vast expense has been one reason, and generally a conclusive one, against such a change. Besides that, most of the plans which have been submitted upon new theories have not been tried at all, or tried upon so small a scale that it seemed to the committee by no means certain that they would be successful when applied to halls of such magnitude as these. In one respect these halls are situated favorably both for maintaining an equable temperature and a healthy ventilation. It is supposed by many that the inclosure of one building within another, the inner one being the hall, is a serious defect in the construction with a view to both these requisites; on the contrary, it is a great advantage. If the hall approached the exterior wall it would be subject not only to all the internal changes of temperature and elements disturbing the ventilation, but also to all those of the external atmosphere and the weather. Almost every one of the disturbing elements that have been named would be greatly aggravated if the hall approached the exterior. It would also be subject to the disagreeable effect of cross-lights and the dazzling effect of the direct action of the sunlight. External influences, like those of noises, winds, and storms, would make themselves felt disagreeably, which are now altogether excluded.

Conceding the advantages of the general structure, and finding that the disadvantage of a forced ventilation could not be altogether overcome, it seemed possible to remove altogether, or to neutralize, some of the existing evils. The first and most serious of these was found in the theory of the forced ventilation, upon which all the apparatus was constructed and arranged. Being dependent for success upon the production of a continuous current in the whole body of the air in the hall from the place of supply to that of discharge, anything which obstructs that current, or prevents the equal discharge, the supply being constant, will impair its efficiency and tend to render it practically useless. What would seem to be the most obvious theory of ventilation, as applied to large halls, was almost entirely ignored in the structure of these buildings. As the foul air is wholly generated within the hall, it might be assumed, as the first requisite of healthy ventilation, that this foul air should be removed. This is the only purpose for which artificial power is needed, as the pressure of the atmosphere is at all times sufficient of itself to force in the fresh external air to fill the space from which the foul air has been withdrawn. It had been suggested by former committees, and the experts whom they consulted, that the fans might be reversed, and be used for exhausting the air from the halls, but no action had been taken upon the suggestion. A step had been taken by the architect in the right direction in 1866, when, as he says in his report for that year, he "found" a large flue in each wing of the Capitol, "running from the cellar and emptying into the loft of the connecting corridors," which he caused to be connected with the smoke flues from the boiler furnaces. How the knowledge of these flues became "lost," subsequent to the completion of the wings, is not

explained. This flue in the House wing has an area of 25 square feet, and withdraws the air from the loft above the ceiling, in quantities depending upon the strength of the draught in the chimneys. It has done good service, but its capacity is not equal to the duty required of it. In the flue in the Senate wing a fan has been placed to operate upon the air above the ceiling by exhaustion, and the effect is so excellent that the committee recommend a similar fan to be operated in the flue upon the House side. They recommend also that this flue be enlarged to double its capacity, which the architect reports can be done without injury to the building, by chipping out one foot in thickness from the surrounding walls, which are now three feet in thickness. An additional engine will be needed to operate this fan. When completed and in operation this fan can discharge 50,000 cubic feet per minute from the loft over the ceiling of the hall, and when both the forcing-in fan and the exhausting fan are in operation the atmosphere in the hall can be changed every five minutes. This would insure a perfect ventilation, if it were certain that only the foul air would be discharged. In order to insure this result the apertures leading from the hall to the loft have been greatly enlarged and distributed over the greater portion of the ceiling. This has been done both in the Senate chamber and in the hall of the House, by simply lifting the iron sash which holds the glass from its seat, thus permitting the air to flow freely through apertures two inches in width, all around each of the squares. The area of the apertures in the outer row of squares is 70 square feet, to which have been added 200 square feet by raising the sashes, making a total of 270 square feet, through which the foul air can be withdrawn from the hall through this flue and through the apertures in the roof.

In order that the supply of fresh air may be delivered in the manner that will insure its most thorough distribution, it is proposed to reconstruct the floor and make a new arrangement of the flues and hot-air pipes under it, so that the air may enter the hall from vertical registers in front of the steps, in all parts of the hall. The nuisance of dust will also be avoided by this arrangement. The plan has been tried in the Senate chamber with complete success.

For the more thorough ventilation of the cloak rooms, chimneys have been chiseled out of the interior walls of the building, and fitted with grates for burning anthracite coal. Tubes, with bell-shaped mouths, have been placed over the gas-burners, and openings have been made from the library and other small rooms into the vestibules. These improvements make the ventilation of the cloak rooms and other small rooms adjoining the hall practically perfect.

The chimneys above the cloak rooms are made to do a double duty. The flue for the products of the combustion of the coal occupies the middle of the chimney, while a flue on each side of it opens at its lower end into the open space beneath the floor of the gallery and above the roof of the cloak rooms. These flues withdraw the air from the galleries and the hall through these spaces, which thus become exhaust-chambers instead of hot-air ducts, as formerly. The effect of these flues upon the air in the galleries is very beneficial. It is recommended that the same improvements be made in the Senate chamber.

The heat from the gas-burners above the ceiling is also a disturbing element in the ventilation of the hall. The temperature of the air in the loft is raised by the heat of the burning gas from 30° to 50° above the temperature of the hall. It is believed that this disturbing element can in a great measure be removed or controlled by the operation of the fan for exhaustion. It is proposed, however, to place tubes and flues

above the burners so as to carry off the heat and the products of combustion in the same manner that they are removed from the cloak rooms. This method, it is expected, will greatly improve the ventilation.

Contrary to the general belief, it has been found, by repeated experiments, that the gas while burning does not increase the temperature in the hall. Thermometers placed immediately under the ceiling and exposed to the full effect of the light, indicated a temperature but 2° higher than that shown by thermometers placed at the height of the desks on the floor, and no higher than that indicated by thermometers at the same level under the shaded portions of the ceiling. Many members have kept on their hats, or used some sort of a shade for the head, to protect it from the heat supposed to be radiated from the burning gas during the night sessions; but it has been demonstrated that whatever discomfort is caused by the burning gas, it is not owing to its radiation of heat. The stained glass of the ceiling intercepts from 25 to 50 per cent. of the light from these burners and all of the heat.

OF THE PLANS SUBMITTED TO THE COMMITTEE.

In response to the invitations of the committe, many plans for the improvement of the ventilation of the halls have been submitted by different parties, some of which deserve and have received a careful consideration.

The most important of these is the plan and proposition of Laban C. Stimers, an engineer of New York. His plan was submitted to a former select committee of the House on the subject, and the proposition now submitted is in further explanation of his proposed improvement.

If a new Capitol were to be built, so that the system proposed by Mr. Stimers might be completely provided for and developed in every part of the structure from the foundation to the roof, his plan might receive favorable consideration from those who had in charge the erection of the new building. But the magnitude of the work, as well as the great expense it would involve, and the length of time required for its completion, have deterred the committee from recommending its application to the existing structure. It is a proposition which in its application to the Capitol as it now is, would be revolutionary in all that relates to the modes of heating and ventilation, and the adoption of which could only be justified by the total failure of the present method and apparatus. His essays form a valuable contribution to the science of ventilation. They will be found appended to this report. His plan requires the erection of structures outside of the Capitol, at a cost, as estimated by the Architect, of upwards of $300,000; and he proposes to furnish the necessary machinery and apparatus, and make the requisite alterations in the Capitol itself, at a contract price of $654,000. The committee became satisfied that the lowest estimate which could be placed upon the cost of the introduction of Mr. Stimers's system of ventilation into both wings of the Capitol would be about $1,100,000.

Another plan is that proposed by Mr. Luther Robinson, of Boston. He expects to accomplish successful ventilation by a number of peculiarly-constructed ventilators in the roof. There are serious objections to the use of such ventilators in connection with the present apparatus for forcing air into the hall, and without altering the structure of the roof and ceiling; and the committee have hesitated to recommend the adoption of Mr. Robinson's plan as a whole. They have, however, come to the conclusion that ventilators in the roof may be of some service in summer, especially over the staircases and corridors, and perhaps

over the hall, if they are made so as to be capable of constant regulation and adjustment. The selection and application of them the committee propose to leave to the judgment of the Architect of the Capitol, guided by experiments to be made after the exhausting apparatus shall have been introduced and tested.

The committee have thought it best to append to this report all the propositions which they have received upon the several subjects referred to them, and also to reprint those portions of previous reports which give the history of the ventilating of the halls. The valuable report of Dr. Charles M. Wetherell, with those of Mr. Walter, the former Architect of the Capitol Extension, and of Professor Henry, of the Smithsonian Institution, on the same subject, are also appended, the original editions having been exhausted. Some observations are added by way of notes which have been suggested by the experiments made under the direction of the committee.

Among the propositions is one from the United States Ice and Refrigerating Company, for the erection and fitting up of refrigerating machines for the purpose of cooling the halls and corridors in summer. Your commmittee are of opinion that an apparatus of this kind for the purpose of cooling the walls of the corridors in the early part of the day in summer, before the hour for committee meetings, would prevent the excessive heat from without from penetrating into the hall, and give a grateful coolness to the air which entered through the wire-gauze doors. A jet of air of a temperature reduced by this apparatus, thrown into the flue through which the external air is forced into the hall, might reduce the temperature from 4° to 5° below what it would otherwise be. On referring the proposition to the Architect he reported that it was not practicable to erect the structures necessary to prevent the escape of the cold air to be used for refrigerating the corridors without disfiguring and obstructing the entrances to the hall and the corridors, and that the other method of utilizing the cold air would require greater alterations in the flues and ventilating apparatus than he thought proper to recommend. These objections, with that arising from the great expense of the apparatus, considering the very short period in summer when it is actually needed, were sufficient, in the judgment of the committee, for not entertaining the proposition. The best method of making an application of this refrigerating process to the necessities of the halls has probably not yet been suggested.

Henry A. Gouge also exhibited his apparatus for ventilation before the committee, and explained its operation and use. It will be found in the appendix. The committee had doubts of its efficiency in so large a structure. It seems well fitted for the cloak rooms and committee rooms. Under the appropriations already made the Architect will be at liberty to test its value in such manner as he may think fit.

Some of these propositions will strike the reader as very singular, and based upon curious ideas concerning the principles of ventilation. But they have all been submitted to the committee in good faith, and as some of them were prepared by parties who had not made themselves familiar with the structure of the halls and the changing circumstances attending their daily use, any apparent eccentricities may be more properly charged to the want of information upon these facts than to ignorance of natural science. It must be remembered that the science of ventilation itself is of very modern date, hardly older than the use of anthracite coal as a fuel, and that its successful application to the hall of the House of Representatives is probably the most perplexing and complicated problem of the kind ever submitted to an engineer.

OF THE MANAGEMENT OF THE HEATING AND VENTILATING APPARATUS.

The series of improvements which will close for the present with those recommended by this committee, will probably furnish the means of adding to the comfort of members while engaged in the hall; but this will by no means remove all the defects in the methods of heating, lighting, and ventilating the halls, as some of these are inherent in the structure itself, and cannot be overcome except by changes which would be essentially revolutionary and enormously expensive. It was said in the House of Commons in England that two hundred thousand pounds sterling had been expended in endeavoring to improve the ventilation of the two houses of Parliament, and that they were little better in this respect than at first. We might expend a like sum in experiments upon theories that seem plausible, but which have never been tested upon a large scale, with a similar result. We may admit that our structures are faulty, and that our apparatus is arranged and operated upon a false principle, but it does not follow that they must be renovated and reconstructed altogether in order to avoid the evil consequences of these errors and defects. Some of the consequences may be averted by comparatively slight changes in the structure and apparatus, and others may be prevented in part, if not altogether, by the watchfulness of attendants. However perfect the theory and correct the principle upon which a system of ventilation on so large a scale as that required in these halls may be set in operation, it will never be entirely satisfactory at all times, unless it is made to adapt itself to the changing conditions and circumstances which attend its use. There are no known contrivances by which it can be made wholly automatic, and there are no well-known and well-settled rules by which the proportion of cause to effect can be determined absolutely in the several elements of which such a system must be composed. Our efforts are at most a series of experiments; a tentative process, out of which perfect symmetry of arrangement in detail of construction and mode of operation may at last be attainable, but which as yet has not been attained.

Many of the inconveniences heretofore experienced have arisen from the ignorance or inattention of those who have been employed as attendants upon the halls. It has not been their fault altogether that they were, when appointed, ignorant of the duties which they ought to perform, or that they have remained uninstructed. Some of them are appointed by the Clerk of the House, some by the Doorkeeper; some are in the employment of the Superintendent of Public Buildings and Grounds, and some of the Architect of the Capitol. There is no good reason why these persons should belong to essentially different corps, but every reason why they should be appointed by, and be under the control of one who can select his employés with regard to their fitness for the duties they have to perform, and who has the skill to teach them what their duties are, and to see that those duties are always well performed. There is not an office connected with the heating, lighting, and ventilation of the halls which does not require a good education and a considerable degree of skill in the performance of its duties. While the House is in session of a cloudy and windy day, it requires the constant attention of one person to adjust the louvers at every change from fair to cloudy, and from clouds of one degree of density to those of another, so that the hall may receive a sufficient degree of light all the time, not seriously affected by the external fluctuations. It requires a greater degree of attention, a better education, and a higher degree of skill in the per-

son who observes the hygrometer and the wet and dry bulb thermometer, to ascertain the relative humidity of the atmosphere, and to know what amount of additional moisture it requires to bring the air in the hall up to the healthy degree of saturation, and to know when and by what means the want should be supplied, and to be able to have it supplied without causing the infusion of an excess of such moisture. Dr. Wetherill says, (p. 80,) that "to add water, whether in winter or summer, requires *intelligent and watchful industry*, aided by a proper psychrometer." This latter instrument is to be found, he adds, in the improved hygrometer. And when the ordinary hygrometric conditions of the atmosphere in the hall are reversed, and there is an excess of moisture, and on the days when the action of all the natural forces is sluggish or inverted, when coal will not burn in the grates, and the chimneys fail to draw, and the air is forced back or falls back in the flues and outlets, notwithstanding all the force of the fans is applied to urge it forward, the highest degree of skill is required to keep the system in action, and to prevent discomfort. So also, it needs constant watchfulness and observation of thermometers, as well as care in adjusting and regulating the supply of steam to the coil of pipes in winter, to keep the temperature of the hall at the proper degree for comfort and health. In summer the same attendant must be constantly using his judgment with regard to the opening and closing of the external doors and windows, in order to help out the artificial with some natural ventilation. If the skill, watchfulness, and activity of these attendants were of the highest degree that could be obtained, then, even with the present system, any positive degree of discomfort could be prevented at all times. With such as can now be obtained, there is no reason why, under a single head and proper management, the healthful and comfortable condition of the hall should not be preserved during the hours that the House remains in session. The committee therefore recommend that all the persons who are employed for the purpose of attending to the heating, lighting, or ventilating of the Capitol be under the direction, control, and supervision of the Architect of the Capitol.

The committee have not obtained any information which enables them to recommend any change which would improve the acoustic properties of the hall. Its "defects and disadvantages," in this respect, are both in design and in construction, and cannot be remedied by any slight alterations. But the committee are of opinion these are of not so much consequence as is generally supposed. It is rather the magnitude of the hall than any peculiarities in its construction which renders it difficult to catch every word uttered by a member speaking from the floor.

OF THE DIFFERENT THEORIES.

The committee have not attempted to decide between the two theories of upward and downward ventilation upon which the engineers divide, and argue earnestly for and against the merits of each. All the arrangements in the hall as constructed are for the use of upward ventilation, and those who have recommended the substitution of downward ventilation have presented no plan of alterations which did not require a very large expenditure of money to introduce, wholly disproportionate to the value of the supposed advantages from its introduction. But the changes and additions recommended by the committee are such that it will be easy hereafter to adopt a downward ventilation if the modifications of the present system fail to produce adequate results. A downward ventilation may to some extent improve the acoustic qualities of the hall,

but it is not believed that such a change will be called for, or, if adopted, that it will be found beneficial.

COST.

The cost of all the alterations heretofore made upon the recommendation of the Committee on the Hall of the House has been about $16,000; of those to be made, including a new fan and steam-engine to operate it, is estimated to be $20,000.

PROPOSITIONS.

The various plans, propositions, and estimates received by the committee from various parties are hereto appended.

APPENDIX.

REPORT OF H. F. HAYDEN, CHIEF ENGINEER OF HEATING AND VENTILATING DEPARTMENT, UNITED STATES SENATE.

HEATING AND VENTILATING DEPARTMENT U. S. SENATE,
May 10, 1870.

SIR: I have the honor to submit the following report relating to the heating and ventilating department under my charge, showing its condition when I first assumed charge of the same, and the improvements that have been made during the past year. I found that there were two serious defects, which had always existed in the ventilation of the Senate wing:

1st. That one of the most manifest and material defects had been the want of proper moisture in the supply of heated air. It must be apparent to those who have given their attention to the subject of ventilation that the only way that heated atmosphere can be made healthful and pleasant to the senses is by a careful process of artificial evaporation. In view of this fact I have endeavored to obviate this difficulty, which I will explain more fully hereafter.

2d. That there was no escape whatever for the vitiated air in the chamber. Two avenues of escape had been constructed by the Architect of the Capitol Extension, but were closed off by the engineer in charge at that time. The air was forced by a fan into the chamber and allowed to take its own course, subject to all the disturbing causes which must necessarily exist in a hall which was without any escape for vitiated air. Therefore the air in the chamber would soon become so impure, and the ventilation so imperfect, that the necessity would be clearly shown of having that method of ventilation changed, so that the supply of heated air could be moistened and made pure and heathful, and the vitiated air removed in order that the same air could not be breathed twice. Dr. Antisell, in his interesting and able report on ventilation of the Senate wing, July 18, 1866, page 4, says:

"Ventilation has for its end and aim the removal of the vitiated air of dwellings and other crowded places, whenever and as fast as it is produced; but it is not possible by ordinary means to remove the vitiated air without its place being filled by air from another quarter, and thus the exit of air and its rëentry appear to be indissolubly linked, yet they ought not to be viewed in too close connection or as of equal importance. The first condition, the extraction of air, is of prime importance. The air which has been used is a poison, and the chief and first step to be taken is to remove it. In doing this one-half of the second condition has been obtained; that is to say, an equal supply of air has been introduced. What remains to be fulfilled of that second condition is to be certain that the new air is both healthful and agreeable to the feelings."

Upon an examination of the main air duct leading from the fan to the Senate Chamber, I found that the apparatus used by Dr. Antisell in conducting a course of experiments on hydration remained as left by him. It was, however, inadequate, as the relative humidity could only be kept at 30°, which was below the healthy minimum. I therefore had the apparatus removed, and have introduced a vaporizing apparatus in the main air duct, so that warm water can be vaporized and diffused in the supply of heated air, rendering it pure and healthful, and the relative humidity in the Senate chamber can be kept at 60° during the winter season.

In using water for the purpose of hydration, great care and attention should be paid to the hygrometric condition of the atmosphere. This can be ascertained at all times by the use of "hygrodeiks," which give the dew point and relative humidity. During

the last session of the Fortieth Congress, and the first session of the Forty-first Congress, while employed as assistant engineer in the heating and ventilating department of the House of Representatives, I began using the "evaporator," situated in the main air-duct leading to the Representatives' Hall, and, by careful application, commencing at 8 a. m. and continuing it until the hall was heated up to the usual temperature of 69°, I soon discovered that the ventilation of the hall was greatly improved, and I am fully convinced that it was due to hydration, as the evaporator had not been in use for several years. In a report made by Charles M. Wetherell during the Thirty-ninth Congress, first session, on warming and ventilating the Capitol, page 80, he says:

"The winter experiments are very interesting, and indicate the cause of the complaints which some have made as to the ventilation. They demonstrate that the difficulty lies in a deficiency of moisture in the air. The absolute dryness of the air in the winter is great, and its relative dryness is vastly increased after it has been raised to the temperature requisite for heating the halls. It will not be necessary to take up the results seriatim to prove this. A glance at the table will show how low the degree of relative humidity is; even when, as in Ex. 56–61, the relative humidity of the external air is 100, that of the halls is below the healthy minimum, and, at times, the moisture falls to 20. The mean relative humidity at 2 p. m., for the external air of the five Januarys of table 1, is 67. The remedy for this defect consists in adding to the air of the halls from sixteen to thirty-five pounds of water per minute for a ventilation of 60,000 cubic feet of air per minute. This moisture must, as was said, for the summer experiments, be added intelligently. Too much water would be as injurious as too little."

The shafts or avenues of escape, which were found closed off, have been opened. They lead from the space between the ceiling and the roof of the Senate chamber, down to the sub-basement, and there they are connected to ascending shafts which lead to the open air. I found them both, however, inadequate, for whatever of escape did take place was insufficient and irregular from defective arrangements. I was at once convinced of the importance of having exhausting power applied at the point where the vitiated air could be removed, and I am indebted to the honorable Secretary of the Navy for the temporary use of one exhaust fan, with engine attached, which has been placed in a horizontal portion of one shaft leading from the descending shaft to the ascending one in the lower basement. The fan has a capacity of about one-fourth as compared with the entrance movement, produced by the fan for the introduction of fresh air. Being unable to secure another exhaust fan for the other shaft, I have substituted a coal stove, which, however, is not equal to an exhaust fan, but assists in the removal of the impure air.

The fan used to supply the committee rooms and passages being of no use in warm weather, owing to the doors and windows being open and the registers generally kept closed, the fan used for the Senate chamber being inadequate to force in a sufficient supply of fresh air during the months of May, June, and July, and more particularly during the evening sessions, I have connected the two main air-ducts so that both fans can be used to increase the supply of air in the chamber when necessary, or may be used separately as before. This improvement having been completed on the 15th of last August, and the experiments on the 20th of the same month, will show the following results. The following tabular statement will show that by a circulation of water through the coils of pipe that are located in the main air-duct used for heating the chamber in cold weather, also allowing a sheet of water to pass down both air-ducts, will not only reduce the temperature to that degree which will keep the chamber moderately cool and comfortable, but will remove all dust that is drawn in by the action of the fans. The following will show the results of the experiments, August 20th, and the different degrees of temperature:

Time.	External air.	Main air-duct.	New air-duct.	Senate chamber.	Galleries.	Space above ceiling.
	°	°	°	°	°	°
10 a. m.	95	95	95	90	92	100

At 10.15 a. m. both fans on Senate chamber evaporators and exhaust fan in operation:

Time.	External air.	Main air-duct.	New air-duct.	Senate chamber.	Galleries.	Space above ceiling.
	°	°	°	°	°	°
11 a. m.	100	85	80	82	85	105
12 m.	103	80	78	81.5	83	108

At 12.15 p. m. the fans were stopped. Had they been in operation longer, the results would have been still more favorable. Many complaints having been made on account of the dryness of the atmosphere in the winter season in the committee rooms and passages of the Senate wing, I have endeavored in part to obviate this difficulty by placing evaporating pans over the top of each one of thirteen coils which heat the above-mentioned rooms and passages, leading water pipes into the same with valves to regulate the supply of water in order that the heated atmosphere may take its own supply of moisture before reaching the registers leading into the said rooms and passages.

In view of the favorable results obtained by the evaporation of water above the coils, I therefore recommend that evaporating pans be placed over the remaining fifteen coils.

Many complaints having been made by the honorable Senators and others in reference to the descending currents of cold air from the ceiling and over the sides of the galleries down on the floor of the chamber, this defect has been referred to by several gentlemen of high scientific attainments, who have written interesting and very able reports on the ventilation of both wings of the Capitol. I am, however, unable to find any remedy recommended by them. In a report on the warming and ventilating of the United States Capitol, by Professor Joseph Henry, he says:

"It is true that in some cases during cold weather descending currents of cold air have been observed, due to the cooling of the ascending columns as they come in contact with the under surface of the roof, as was evident from the odor of gas when the burners above the ceiling were first lighted. That there is a tendency to form such descending currents is clear, since, unless the air is immediately withdrawn from the space beneath the roof before it is cooled, and thus rendered heavier than the ascending air, it will descend in parallel streams, but to determine how frequent and extensive these currents are, further experiments will be necessary."

Experiments on the 8th, 9th, and 10th of January last show that the descending currents of cold air seemed to be confined to the northeast and southeast corners of the chamber, commencing at the Vice-President's chair and extending around to the doors leading to the rotunda. On the northwest and southwest sides the currents ascend with considerable regularity. The cause of this defect—the descending currents of cold air from the ceiling—is owing to the difference of temperature at the ceiling and the space above it, and the material of which the ceiling is composed.

The heated air ascends until it comes in contact with the cold, metallic surfaces, when it becomes suddenly reduced in temperature below that on the floor, and all that fails to pass through the perforations becomes heavier than the air below, and will therefore descend until it reaches the floor. Coils of steam pipe have been placed above the square registers located in the space above the ceiling, so that the temperature of the atmosphere can be raised to or above that of the air on the chamber floor, which, I believe, will obviate in part, if not entirely, this difficulty, for whenever the ceiling is lighted I find that the cold air ceases to descend; the steam can then be closed off. For the purpose of improving the present method of ventilation of the Senate chamber, I respectfully recommend that escape pipes be made and connected to the square registers located in the space above the ceiling, and that they be conducted into the escape shafts, and all other perforations be closed, so that the gas-lights above cannot affect the air in the chamber, and that the shafts of escape be enlarged so that they will have a capacity adequate for the removal of vitiated air, and that two exhaust fans, having a capacity of three-fourths as compared with the fans for the introduction of fresh air, be placed in the sub-basement for that purpose.

The expenses attending the improvements herein recommended are as follows:

Two exhaust fans	$4,000
One engine	2,000
Escape pipes	800
For enlarging escape shafts, and setting engine and fans	1,500
	8,300

It will be seen, therefore, that, with a comparatively little expense, a pleasant and wholesome ventilation can be secured, without producing any unpleasant currents whatever.

Respectfully submitted.

H. F. HAYDEN,
Chief Engineer Heating and Ventilating Department U. S. Senate.

Hon. J. W. NYE,
Chairman Joint Select Committee on Ventilation.

ARCHITECT'S REPORT ON PROPOSED IMPROVEMENTS.

ARCHITECT'S OFFICE UNITED STATES CAPITOL EXTENSION,
Washington, D. C., February 6, 1871.

SIR: I have the honor to state herein the changes which have been made under the direction of your honorable committee, in order to improve the lighting and ventilation of the hall of Representatives.

A row of iron panels around the skylight in the ceiling has been taken out, and panels of ground glass substituted. Gas-lights have been placed over these. The louvres or blinds under the outer skylight have been so arranged as to admit of all on one side being adjusted at the same time, thus rendering it easy to open all the light, or to so cut it off as to prevent the rays of the sun from coming into the hall.

No change has been attempted in the system of ventilation, but some efforts have been made to make it more efficient and to correct some disturbing causes.

The under side of the copper roof has been plastered, by which radiation in cold weather, causing draughts to descend, particularly at the back of the galleries, has been overcome.

The galleries have likewise been made more comfortable by converting the space between their floors and the ceiling of the coat rooms below into an exhausting chamber, instead of hot-air ducts, as heretofore.

Fire-places have been made in the cloak rooms, and ventilators placed over all gas-lights, running to the hot flues. Windows have been pierced at several places at the ends of these rooms. These constitute the principal changes, and, so far as I have observed, they have been attended with marked success.

There are other improvements which observation and experience suggest, which, if executed, will, in my judgment, go far in perfecting the present system of heating and ventilation.

The flues for the egress of foul air should be enlarged. At present the area of discharge is 25 superficial feet, while the flues are capable of being enlarged to twice that capacity—a size sufficient for all purposes.

The under side of the roof over the corridor should be plastered to prevent radiation and air leaks, and ventilating caps should be placed over these corridors, so arranged that in cold weather, when strong winds from a southerly direction pack against the dome, they may be closed, to prevent currents of cold air descending. I suggest also that the small registers in the floor be taken out, as they are now receptacles for dust and tobacco, and their places supplied by registers in the front and ends of the platforms. In case the change of the register is made I would recommend that the old floor, which is nothing but a piece of patchwork, be taken up and a new floor of walnut put down.

The heating flues under the floor should also be rearranged. I will here state, as I have already verbally, that I consider it very important to the proper working of the heating and ventilating apparatus that an attendant should be placed in the loft to attend to the adjustable parts there, as the weather and the state of the light and winds may demand.

Below is submitted the estimated cost of the further improvements herein proposed:

Enlarging foul air shaft	$2,500
Plastering ceiling of corridors	500
Readjusting flues under floor	1,000
New register	500
New floor of walnut	4,000
	$8,500
Eight ventilators on roof	1,200
Total	$9,700

If your committee should determine to use fans for the expulsion of the vitiated air, a further sum of $7,500 would be required for them and for the necessary steam-engine.

Very respectfully, your obedient servant,

EDWARD CLARK, *Architect.*

Hon. THOMAS A. JENCKES,
Chairman Select Committee on Ventilation,
United States House of Representatives.

ARCHITECT'S REPORT ON COOLING APPARATUS.

ARCHITECT'S OFFICE, UNITED STATES CAPITOL EXTENSION,
Washington, D. C., February 23, 1871.

SIR: I have examined the proposition of Mr. L. Bouvier for cooling the corridors of the House of Representatives by means of Tellier's refrigerating machine.

Mr. Bouvier says, to effect this, all the doors and windows leading out from the corridors must be kept as securely closed in summer as in winter, and that double partitions, with doors, must be put in at each end of the connecting corridor. This arrangement, I consider, would prove very unsatisfactory, if not impracticable; it would further aggravate what many consider the most objectionable feature in the present plan—the absence of lateral ventilation. While I am anxious to see experiments tried to obtain more comfort, yet I consider this undertaking unreasonably expensive to obtain, at best, a doubtful result.

I would be glad to see a small refrigerating machine used in the main air duct, in order to lower the temperature a few degrees in hot weather, which, I believe, could be done at an expenditure of a few thousand dollars.

The papers referred to me are herewith returned.

Very respectfully, your obedient servant,

EDWARD CLARK,
Architect.

Hon. THOMAS A. JENCKES,
Chairman Committee on Ventilation,
United States House of Representatives.

Hon. THOMAS A. JENCKES:

DEAR SIR: At your request, please find estimate for making a change in the arrangement in lighting the ceiling of the hall of Representatives, viz: To light the new border panels without lighting the center panels, it will require an independent service pipe, running the entire length of the border panels, as also an independent magnetic engine for turning on or off the gas with one line of isolated wire. The following is a correct estimate:

For 2½-inch gas-pipes, with fittings, &c., complete	$450 00
For magnetic engine and stop-cock complete	500 00
For isolated wire	6 00
For electric connection key to instrument	5 00
For labor	80 00
	1,041 00

Yours, respectfully,

SAM'L GARDINER,
Electrician.

The committee ordered the work, for which the foregoing estimate was made, to be done, and have paid for the same out of the appropriation to be expended under their direction. The beneficial effect of the alteration can be perceived whenever the lighting of the hall takes place during the twilight. The burners over the new plates of ground glass sometimes furnish sufficient light for the hall without lighting those over the large squares. Until this alteration was made all the burners had to be lighted at the same time.

EFFECT OF HEAT FROM THE BURNING GAS IN THE SENATE CHAMBER.

Temperatures of the United States Senate, June 24, 1870.

Time.	External air.	SENATE CHAMBER.				GALLERIES.		BELOW CEILING.				ABOVE CEILING.			
		Northeast corner.	Southeast corner.	Northwest corner.	Southwest corner.	North side.	South side.	Northeast corner.	Southeast corner.	Northwest corner.	Southwest corner.	Northeast corner.	Southeast corner.	Northwest corner.	Southwest corner.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
7 o'clock p. m.	86.0	83.5	83.5	83.0	83.5	83.0	83.0	88	88	88	88	90	90	89	92
8 o'clock p. m.	85.0	84.5	84.5	84.5	84.5	84.0	84.0	88	88	88	89	123	125	125	125
9 o'clock p. m.	84.5	85.0	85.0	85.0	85.0	84.0	84.0	89	89	89	89	122	122	122	122
10 o'clock p. m.	84.5	84.5	84.5	84.5	84.5	83.5	83.5	88	88	88	88	122	122	122	122

PROPOSITION OF HENRY A. GOUGE.

To the Honorable John Covode, Chairman of the Committee on Public Buildings and Grounds:

SIR: In presenting my system of ventilation for the consideration of your committee, I beg leave to call your attention to the following:

The present appliances for ventilating the House of Representatives fail utterly to accomplish that object. It is true that currents of fresh air are *forced into* the apartments, but they, from their nature, put obstacles in the way of accomplishing the object sought, by producing counter or eddying currents; and, in addition to this, the means of egress for the vitiated air are inadequate and very imperfect. Of course, if air is forced *in*, air must be forced out; probably that was the theory on which the present system was based. But in this case the greater portion of air thus forced in leaves the hall precisely in the condition it entered, and its egress is at the doors to a great extent.

The copper roof and space between the roof and ceiling are great obstacles in the way of ventilation, the more so because the space communicates, through holes in the ceiling, with the hall below. In the winter the heated air rises to the ceiling along the walls, and creeping thence to the openings in the ceiling to the cold space above where it is condensed, (the copper roof conducting off the heat very rapidly,) and falls of its own gravity through the openings nearer the center of the ceiling to the floor of the House, where its influence is disagreeably felt. The danger of a cold wind on an uncovered head need not be enlarged upon. In this case the danger to health is increased because the descending current has all the deleterious gases and impurities of the ascending current; some of it escapes, no doubt, but the accumulation when the hall is full of people is very rapid, as your committee well know, and I will not enlarge upon it; my object being merely to show why the apparatus used for ventilating the hall fails of accomplishing the duty. Its principal defect is that which I have stated.

The copper roof and space beneath it interfere with the ventilation in summer quite as much as in winter, although from different and nearly opposite causes. The roof absorbs the heat of the sun's rays, and communicates it to the air in the space beneath, and often raises it to a temperature 30° and 50° above that of the external atmosphere, thus heating the ceiling, which radiates powerfully on the heads below; and the eddies produced by the forced currents of air from the registers induce downward currents of this air from the reservoir above; thus the temperature of the apartment is kept up to a high degree. The eddying currents of air cannot be avoided where direct streams are forced.

My system consists of forcing the vitiated air out of the apartment, and supplying its place with pure air from outside the building. It will absolutely prevent the currents of cold air from above in the winter and hot air in the summer, as it is my purpose to destroy communication between the hall and the reservoir above, and to prevent radiation from the ceiling. This can be done very easily.

My system of ventilation will, without the aid of any machinery, or power applied externally to the ventilating tubes, completely *change the air in the hall as often as may be desired*; fresh air being constantly supplied through tubes under the floor and furnished with registers.

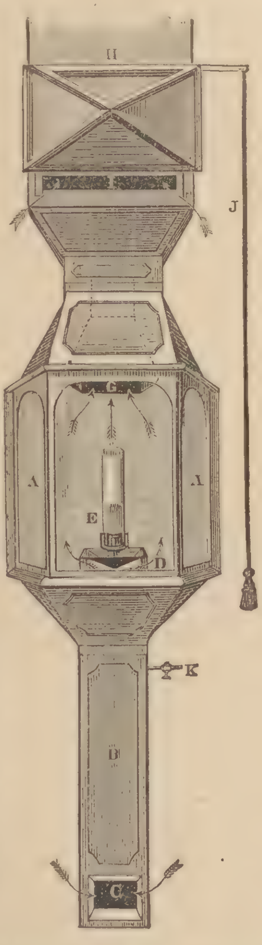
To prepare the hall for my ventilating tubes to work successfully, it will be necessary to close up the holes in the ceiling, which are fruitful sources of trouble, not only as regards ventilating, but also by interfering with the acoustic properties of the hall. To do this I propose to cover the entire ceiling, excepting the glass panels, with hair felt, which, being a non-conductor of heat, will effectually prevent the ceiling from being affected by the temparature of the space above it, and by this single precaution overcome two very important difficulties in the way of perfect ventilation.

My ventilating apparatus consists of tubes running from the floor to a proper distance above the roof. These tubes are provided with openings at the floor, ceiling, and such intermediate points as may be deemed expedient. In the tubes, and at a proper distance above the floor, I place a lantern containing an "argand" or other burner, consuming gas or whatever may be most convenient. The burner is placed in the center of the lantern and serves to produce a powerful upward current. By placing a pyramidal tube or inverted funnel over the burner the current of hot air is contracted and its speed augmented, which, entering a duly expanded tube above, induces another current of great force. Openings are provided above as stated, and the air supplied at these openings augment largely the ascending current, the tube being properly expanded at each opening.

To adapt this to the hall of the House of Representatives, the tubes are placed in the wall running up behind the niches in the gallery (twenty-eight in number) entirely out of sight, and extending down into the coat rooms under the gallery, where the lantern is placed, which, while giving motion to the column of air, sufficiently lights the apartments. Openings are made through the partition into the hall, at the floor, from

GOUGE'S ATMOSPHERIC VENTILATOR.

PATENTED MAY 26, 1863; APRIL 25, 1865; AND MAY 9, 1865.



A. A Ventilating Lantern, with an Argand burner.

B. Ascending flue or air duct.

C. Opening in duct at or near the floor, for the admission of air.

D. Diaphragm for regulating the admission of air to the gas jet at E.

G. Opening of interior flue for concentrating the heated and expanded air.

H. Ascending portion of the large flue or metalic air-duct, terminated above the roof by a weather cap.

I. Aperture into which the foul and heated air at the ceiling is drawn by induction.

J. Cord for opening or closing the register at I.

K. Tube for conveying gas to the gas-burner at E.

☞ The arrows indicate the up-moving currents of air.

☞ The combustion of the gas jet at E is supported by the air which enters at C, and along with this air, which acquires a powerful ascensional force through the burning gas jet, the carbonic acid, and other impurities, ascend and mingle with the heated air and lighter noxious gases which enter the ventilator at I, all passing upward and onward, by virtue of an irresistable motive power, until they are finally discharged into the atmosphere. See illustration, page 4, and "Further Explanations," etc, page 48.

WEATHER CAPS

FIG. 1

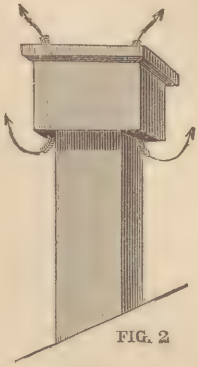


FIG. 2

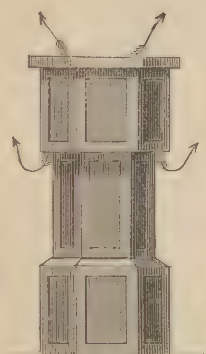


FIG. 3

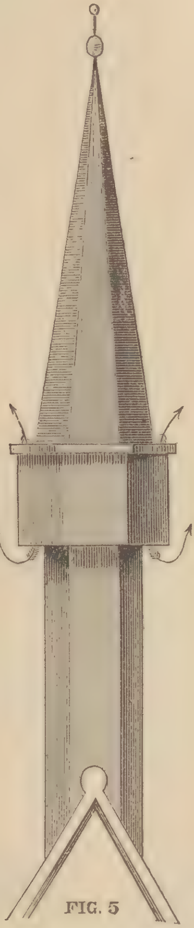


FIG. 5

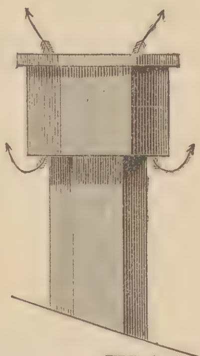
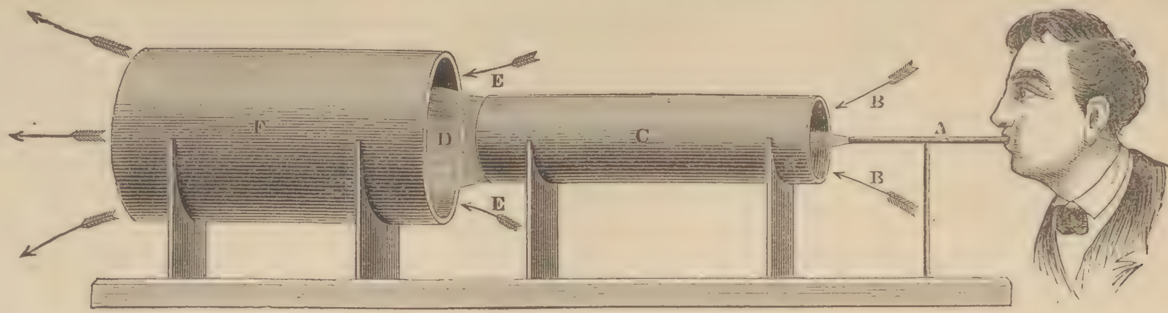


FIG. 4

Explanation.—The Weather Caps here represented, and indicated by numbers, are used in connection with GOUGE'S ATMOSPHERIC VENTILATOR. They are varied in style, according to the architectural design of the building to which they are to be attached, and are so constructed as to prevent the admission of rain, snow or wind, while they permit the currents of air from the interior of the building to pass freely into the atmosphere.

INDUCTION OF AIR—MOTIVE POWER OF VENTILATION.



Explanation.—A, Small tube through which air is blown, constituting a primary current, represented as passing into the larger tube C. B, B, Arrows indicating the direction of the induced currents of air, which are put in motion by the primary current. D, Second primary current of air passing from C into F. E, E, Induced currents, resulting from the primary current D. From F the air escapes into open space, as indicated by the arrows.

☞ The induction of air, as represented by the above figure, is the essential motive power of "Gouge's Atmospheric Ventilator." Through this induction, powerful up-moving currents of air are obtained, without which there can be no efficient ventilation. But little heat is required for the purpose, which may be furnished by a gas-jet, kerosene lamp, or other equivalent. Some have argued that it is impossible for so slight a cause to produce so powerful an effect. This is a mistake. Rarefaction of the air is indirectly one of the most powerful forces in Nature. It produces the storm and the tornado. The warm air of the Gulf Stream, through its rarefaction, causes the colder air of the Atlantic to rush in with an unceasing force to fill the vacuum. We have only sought to imitate Nature. Much, however, depends upon the proper construction of our ventilating apparatus in reference to its efficient working. See Illustration opposite to the title page, and "Further Explanations," etc., page 48.

the coat-rooms where the air is by the ventilating tubes through the openings at the floor and ceiling. In the hall, above the niches and immediately under the ceiling, other openings are made for the admission of the lighter vitiated gases from the apartment. These openings are covered by neat and ornamental shields, which can be embellished with the coat of arms of the United States or other approved design. The openings themselves are provided with registers by which the flow of air can be regulated. The tubes extend to the roof, where weather caps, constructed in conformity with the design of the building, are placed.

The tubes for supplying fresh air are located under the floor leading to the open air, and provided, at their inner termini, with neat registers.

By reference to the accompanying drawings the operation and location of the ventilators will be apparent.

Yours, very respectfully,

H. A. GOUGE,
254 *Broadway, New York.*

To the Honorable James M. Nye, Chairman of the Joint Special Committee of both Houses of Congress on Ventilation:

SIR: My theory of ventilation is explained in my book on that subject, which I have had the honor of placing in the hands of your committee. It will be seen that I discard the use of steam-engines, fan-blowers, and all kinds of machinery, and depend upon a more simple and economical form of apparatus, namely, a system of metallic air-ducts or air-carriers, in combination with what I term "ventilating lanterns" and weather-caps. The lanterns may be regarded as induction tubes, and are also useful in diffusing light when this is necessary. The weather-caps are the termini of the metallic air-ducts above the roof, and are so constructed as to be in harmony with the architectural design of the building. The air-ducts carry off the poisoned air from the apartment to be ventilated more efficiently than could be done by the forcing operations of a steam-engine. This is accomplished through the simple law of induction, as explained in my book. It will be seen that the forces of nature, properly guided by the hand of art and science, are more than the equivalent of the steam-engine or any similar motive or forcing power for the purposes of ventilation. The vitiated air steadily ascends through the air-ducts in obedience to a powerful ascensional force, and finally mingles with the great ocean of atmosphere above the roof, where it can no longer poison the blood or stupify the brain. This result takes place without any superintending care during the day or night, and does not involve any expense, excepting what is necessary for a limited number of Argand burners or other equivalent lights. While the impure air is passing upward and onward through the air-ducts, the fresh external air is admitted into the interior of the building through appropriate channels to take its place. The in-flowing air is heated or otherwise, according to the necessities of the case. Thus, we have at our command a bountiful supply of fresh air, which I need not say to your committee is indispensable to life and health, as well as to physical and mental power.

A reference to my book will apprise you of a large number of public and private buildings in New York City and other places, which I have ventilated successfully. You will find the names of many distinguished and well-known gentlemen as my indorsers. You must judge of me by my works. My motto has been, and still is: "No success, no pay." I found in the course of my professional experience that immense sums of money had been paid for experiments in ventilation which proved to be failures, and not wishing to occupy an empirical position in the business of ventilation, I formed the habit of saying to applicants for my professional services that I would either ventilate their houses or buildings successfully or make no charge for my services. On this platform and with this pledge, I am willing to undertake the ventilation of the Capitol or any portion of the same. To be explicit, I will agree to ventilate the House of Representatives and furnish all the material and labor for $50,000. The ventilation will include all the rooms under the gallery.

There are many details in regard to the proposed ventilation with which, perhaps, I need not trouble the committee. I will, nevertheless, make a few explanatory remarks. First of all, I will refer to the copper roof and the space between it and the ceiling, which are great obstacles to ventilation both in summer and winter, but from different or opposite causes. The space under the copper roof communicates through apertures in the ceiling with the hall below. In winter the cold air descends through these apertures to the floor of the House, where it makes an unpleasant impression upon the members. It is also highly prejudicial to health, as it carries with it, in a condensed form, all of the poisons of the heated atmosphere. In summer the air space under the roof becomes exceedingly hot, and is frequently from 30° to 50° above the temperature of the external air. The ceiling becomes heated as a necessary consequence, and radiates its heat very uncomfortably to the hall below. Moreover, the forced currents of air from the registers induce downward currents of air from the heated reservoir above, which I need scarcely say is highly objectionable and prejudicial.

Should I ventilate the hall, as specified, it would be necessary for me to close the apertures in the ceiling, which, in addition to the objections already named, interfere with the acoustic properties of the hall. In doing this, it would be necessary for me to cover the entire ceiling, excepting the glass panels, with hair felt, which, being a non-conductor of heat, will prevent the ceiling from becoming heated in summer or chilled in winter, and thus two important difficulties in the way of ventilation will be obviated.

It will be a part of my plan to place the air-ducts in the wall, behind the niches in the gallery, (twenty-eight in number,) where they will be entirely out of sight. They will extend downward into the coat-rooms under the gallery, where the lanterns will be adjusted, and which, in addition to ventilating purposes, will sufficiently light the various rooms. I will not trouble the committee with further details, as I hold myself in readiness, if called upon, to furnish the committee with any additional explanations which they may desire.

I will add that I propose to make the air-ducts within the hall of galvanized iron, while the weather-caps, and everything above the roof, I propose to make of copper. This is also the judgment of the Architect of the United States Capitol, Edward Clark, esq., in which I entirely coincide.

I have the honor to subscribe myself, very respectfully, yours,

H. A. GOUGE.

NEW YORK, *March* 22, 1870—254 *Broadway.*

PLAN AND PROPOSITION OF ALBAN C. STIMERS FOR THE VENTILATION OF THE HALL OF THE HOUSE OF REPRESENTATIVES, SUBMITTED TO A SELECT COMMITTEE OF THE HOUSE IN THE FORTIETH CONGRESS.

[REPORT NO. 19.]

OFFICE OF ALBAN C. STIMERS, NAVAL ENGINEER,
No. 45 *William Street, New York, December* 15, 1868.

SIR: Agreeably to your request that I should prepare for the committee a detailed report which should express my views upon the proper method of ventilating the hall more fully than was done in my letter to you upon this subject dated July 20, 1868, I beg leave very respectfully to submit the following report:

The term *ventilation*, when applied to a hall of this importance, should signify *the production and maintenance within doors of pure air, properly tempered with heat and moisture, regardless of the existing state of the weather.*

Thus, to maintain the air pure in any inclosed space occupied by persons, it must be constantly renewed; when the weather is cold, the air of renewal must be warmed; when it is hot, it must be cooled; when it is too dry, it must be moistened; and when it is too moist, it must be dried. Further: when air is warmed simply, its relative humidity is lessened; and when it is cooled, this is increased; so that generally, when air is warmed, it must be moistened; and when it is cooled, it must be dried.

Properly, however, the degree of moisture in the space ventilated should be as carefully observed as that of its temperature, and that which is most pleasant and healthful should be uniformly maintained, regardless of the condition of the outer air, or of the modifications which may have been made in its temperature.

A consideration of the subject is therefore properly divisible into the following heads:

1. The quantity of air necessary and how it should be introduced.
2. Warming and moistening the air in cold weather.
3. Cooling and drying the air in hot weather.

The subject of regulating the degree of moisture in the air when it is neither warmed nor cooled, is naturally involved in the above.

I. THE QUANTITY OF AIR NECESSARY AND HOW IT SHOULD BE INTRODUCED.

In treating of the quantity of air required for ventilation, writers generally refer to the number of cubic feet required per minute for each person in the apartment. This mode does not, however, take into consideration the vacant spaces where the air comes and goes without having come in contact with persons.

Every person is at all times surrounded by an envelope of vitiated air, and the thickness of this envelope is dependent upon the direction and velocity of the air past the person. Thus, the average man is 5 feet 8 inches high, and 1 foot thick from front to back. If, therefore, the direction of the current of air past the person is vertical, it will require to have $5\frac{2}{3}$ times the velocity that would be necessary, if the direction was horizontal, to maintain the same thickness or rather thinness of the vitiated envelope.

Dr. Wetherill, in his very interesting and able report on the ventilation of the Capitol extension, page 66, says:

"Hood (Warming and Ventilation, p. 261) estimates the air required for ventilation by the amount needed to take up the moisture from the skin and lungs. The air required for respiration (*i. e.*, oxidation) is very much less than that needed to hold in solution the vapor of the skin and lungs, which evolve 12 grains of water per minute. If the temperature of a room be at 60°, with a dew-point of 45°, a cubic foot of air will absorb $2\frac{1}{4}$ grains of vapor; or, in other words, the perspiration from the body will saturate $5\frac{1}{4}$ cubic feet of air per minute. If, however, we take the dew-point lower, say not to exceed 20° or 24°, then $3\frac{1}{4}$ cubic feet of air per minute will be required to carry off the insensible perspiration; while for the pulmonary supply one-fourth cubic foot will be needed, making a total of 4 cubic feet. In summer, as the dew-point is higher, more air will be needed, viz, 5 cubic feet per minute for summer ventilation."

In a foot-note to the above it is stated that Seguin gives the exhalation of water from the lungs, 7; from the skin, 11; total, 18 grains per minute.

This is undoubtedly the correct method of ascertaining the number of cubic feet of air vitiated by each person per minute, and, as will appear further on in this report, the dew-point should be maintained uniformly at 52°. Assuming this, we can make the calculation of quantity exact for this case.

A cubic foot of air at a temperature of 65°, with the dew-point at 52°, will absorb $2\frac{1}{2}$ grains of vapor, and if we take the mean of the two authorities above cited, regarding the quantity exhaled by each person, we will have 15 grains per minute, and to absorb this under the above conditions will require 6 cubic feet of air. Add to this the one-fourth cubic foot required for breathing, and we have $6\frac{1}{4}$ cubic feet as the total amount vitiated per minute.

The surface of an average man is about 18 square feet. If, therefore, we imagine such a man walking in the pure open air at the rate of two miles an hour, on a perfectly calm day, the air will be flowing past him at the rate of 176 feet per minute, and, as he is one foot deep from front to back, the average thickness of the envelope of vitiated air which surrounds him may be found as follows:

Let a = The quantity of air vitiated per minute in cubic feet .... = $6\frac{1}{4}$
b = The surface of the person in square feet.......................... = 18
c = The extent of the person in the direction of the current of air in feet. = 1
d = The velocity of the current in feet per minute.......................... = 176
x = The thickness of envelope in inches—

$$\text{Then } \frac{12\,ac}{bd} = x,$$

and $x = 0.018$, or $\frac{1}{55}$ of one inch.

In supplying air for the ventilation of a hall containing an assemblage of people, however, it is absolutely essential that the direction of the current should be vertical; otherwise that which has been vitiated by one person will be given to another to breathe and perspire into.

If, now, we assume a man standing upright of the average height of 5 feet 8 inches, and the velocity of the current at 5 feet per minute, we will have for the value of the terms in the above formula:

$$a = 6\tfrac{1}{4}$$
$$b = 18$$
$$c = 5\tfrac{2}{3}$$
$$d = 5$$

Whereupon $x = 4.16$ inches.

If this envelope of four inches thickness of vitiated air be drawn upward, it is clear that the nose and mouth will be always supplied entirely with vitiated air, no matter how pure it may be one foot away; while, if it is drawn downward, those organs will always be supplied with perfectly pure air.

This consideration alone is quite sufficient to determine us in favor of the downward direction; there are, however, some other advantages in the downward over the upward direction, which it may be well to state.

The temperature of the human body rarely varies 2° either way from 98°, a sudden variation of 5° or 6° being said to be fatal. If, therefore, the air is supplied at a temperature of 65°, it will be 32° cooler than the body; with the downward current the head will be in this cool air, while the feet will be inclosed in an atmosphere nearly if not quite as warm as the blood within them. And to "keep the head cool and the feet warm" is one of the fundamental rules of hygiene as well as of comfort.

A current of air coming up through the floor will always bring along with it the fine dust, which the greatest care cannot prevent accumulating there to an extent which renders it unpleasantly sensible in all assemblages supplied with an upward ventilation. With the downward ventilation it is only necessary that the dust shall be thoroughly removed from the inflowing air at the mouth of the inlet duct to maintain the hall perfectly free from dust. To say nothing of the advantages of this on account

of health, the freedom from dust upon the papers to be handled is a luxury every one would keenly enjoy.

Again: with upward ventilation the entire hall is filled with vitiated air, the vitiation having taken place near the point of admission: while with downward ventilation the vitiation takes place near the point of exit, and the whole upper part is full of pure air.

The height from floor to ceiling of the hall is 36 feet; if, therefore, the air is admitted through apertures well distributed in the ceiling, it has 30 feet to move before it comes in contact with the heads of persons on the floor. During this movement all eddying currents, induced by the increased velocity with which it is necessary that it shall pass through the apertures, have become quiet, and the whole mass descends with a uniformity impossible to obtain in the vicinity of the persons ventilated with upward ventilation; and one of the most important considerations to be kept in view in ventilating an apartment is to avoid perceptible draughts.

Mr. Goldsworth Gurney, in his examination before a committee of the House of Lords of the British Parliament, March 24, 1854, said, in reply to the question:

"In those courts which you have ventilated you have found your system answer?

"Yes, we have found the down-current always more agreeable. The up-current is sometimes used, but it is not so pleasing, and not so effectual."

The hall of the Massachusetts house of representatives has recently been provided with new ventilating arrangements, and the downward system has been adopted. The success of the entire arrangement is said to be highly satisfactory.

One objection brought against the downward system is that it is against nature to force air downward. Although this opinion is entertained by an extremely large number of otherwise well-informed persons, every engineer of ordinary attainments knows perfectly well that it is as easy to force air in one direction as another.

Another objection is, that as the air is warmed at the same time that it is vitiated, that which is thus vitiated and warmed has a tendency to rise, whatever may be the direction of the general mass surrounding it. This is true, but this tendency is so feeble that its opposition to a current of 5 feet per minute would not be perceptible.

It has been shown that with a vertical current of 5 feet per minute, the mean thickness of the envelope of vitiated air surrounding a man of the average size, when standing, is 4 inches. This is more than two hundred times as thick as when he is walking at the rate of two miles an hour in a perfect calm. As, however, the air is to be brought from such a direction that the mouth and nose are always supplied with air of absolute purity, and the velocity is sufficient to insure the control of its direction by the mechanical means employed, I have assumed it for the *minimum* velocity to be given.

When the weather is fine, or, in other words, when the outer air, from which the supply is derived, is in the desired condition as regards temperature and moisture, and no expenditure is required upon its condition, then a *maximum* amount may be given, the *minimum* being employed when its condition as regards temperature and moisture has to be changed to the greatest extent. The only limit to the amount of air it will be advantageous to supply is that fixed by the rule that the currents past the person must not be sufficiently rapid to become sensible. Some persons are sensible to currents of much lower velocity than is required to render others conscious of them. Most people can feel a current having a velocity of 150 feet per minute; very few can perceive one of 90 feet per minute. To be quite sure that no one, however delicate, should be conscious of being in a current, I would fix the *maximum* velocity at 50 feet per minute. This will render the average thickness of the envelope of vitiated air surrounding each person, when standing, two-fifths of an inch thick, or twenty times thicker than when he walks at the rate of two miles an hour in a calm. This is stated to show that the *maximum* velocity adopted is not an extravagant one.

The hall is 139 feet 4 inches long by 93 feet wide. The downward current within it would, therefore, have a transverse area of 12,958 square feet. A velocity of 5 feet per minute would then require a supply of 64,790 cubic feet; and one of 50 feet per minute, 647,900 cubic feet per minute. In the arrangement I would propose, the various committee and other rooms would be supplied from the same source as the hall, and to supply these the foregoing quantities should be increased to 80,000 and 800,000 cubic feet respectively. The provisions for heating, cooling, moistening, and drying the air, should therefore correspond with the lesser, while those for propelling it into and out of the building should be adequate to control the greater of the above quantities.

The first method adopted by engineers and architects to give movement to air for the ventilation of mines and buildings, was to heat an upflowing column, thus lessening its specific gravity, and causing it to rise with corresponding force. That system is still employed in the British houses of Parliament, where, in each of its many towers, a charcoal fire is kept burning, and thus a force obtained to propel the air through the building.

It has been practically demonstrated, however, that one pound of coal burned in the furnace of a steam-boiler which furnishes steam to drive a fan-blower, will generate as

much force, and consequently is capable of producing as strong a current of air, as 38 pounds expended in heating a column of air to act by its diminished gravity.

English mining engineers commenced about ten years ago to apply fan-blowers to the ventilation of mines. The French had previously adopted the same practice. In addition to the economy of this method, the complete control which the attendant is enabled to maintain over the quantity of air supplied at all times, is found to be of great advantage.

To propel the air into the hall, therefore, I would employ four fan-blowers, having a capacity of 200,000 cubic feet per minute each. I would place these near the northern end of the large central chamber in the cellar, as shown in the plan of foundations, Plate I, and in the sectional elevations of the House wing, Plates II and III, attached to this report. Thence the air passes both east and west, as shown by the arrows, to the extreme ends of the building, where it passes up through shafts situated between the grand stairways and the outer walls to the chamber above the ceiling. Here I would provide an additional ceiling of plate glass and iron, of double thickness, that it might be a non-conductor of heat, and above this I would fix the gas-burners. This forms an air-duct, as shown by the sectional elevations, Plates II and III, of such a character that the air may be thoroughly distributed over the ceiling before passing into the hall. As the glass would be of the best quality of clear plate, it would be no perceptible obstruction to the light, while, as there would be six inches depth of confined air between the two thicknesses, neither the heat of the summer sun nor that of the numerous gas-lights would raise the temperature of the inflowing air; and in winter it would equally protect the warmth which had been previously given to it. Openings through the present ceiling would be provided, such that its present ornamental appearance would not be changed, and an equal area of opening would be obtained in each of the 165 squares into which it is divided.

To insure the continuance of the air thus admitted through the ceiling in a direct vertical line down to the floor and to the galleries, frequent openings throughout their extent, which should communicate to the air-chamber beneath the floor, would be provided, as shown in Plates II and III, especial means being provided to prevent the foul air from the galleries from flowing down upon the members on the floor; and from these I would withdraw the air by means of four fan-blowers of equal dimensions with those employed to drive the air in, but I would drive them only three-fourths the velocity given the others, as the air which ventilated the committee rooms, though supplied from the same source, would not pass through these. These blowers are shown at the ends of the building in the illustrations. From them the air passes up through a separate duct, by the side of the pure air-duct already mentioned, back of the grand stairways, and goes off through the roof.

All these blowers would be driven by one pair of engines of 750 horse-power, through the medium of appropriate gearing, shafts, and belts, as shown in the plates. In every case of gearing there would be wooden teeth working into cut-metal gear, which, it is well known, may be made to run with perfect silence, and is more durable than metal gearing. By running all the blowers from one engine, a uniform relation of the forces employed in different localities is thoroughly secured under all circumstances.

It will thus be perceived that the air would be driven in through the ceiling and drawn out through the floor with equal forces, and that if the doors are left open into the corridors, either from the floor or from the galleries, there will be no tendency for the air to flow either into or out of the hall. At present the provision for the egress of the air through the ceiling is so much greater than that for forcing it up through the floor, that there is a constant flow into the hall from the corridors through every open door, both on the floor and in the galleries. (*Vide* the Hon. John Covode's report on the ventilation of the hall of the House of Representatives, made June 20, 1868, p. 2.)

If the forces employed to drive the air in through the ceiling were greatly in excess of those provided for drawing it out through the floor, and the doors were left open, the direction of the current would be changed from the direct vertical line to oblique ones toward the doors, and while those sitting near the walls might get their full share of pure air, those in the center of the floor would not.

Again, if the forces for withdrawing the air were greatly in excess of those for supplying it, the air would flow into the hall from the corriders through the open doors, disturbing the direction and equal distribution of the pure air, and interfering with whatever modifications there had been made in its condition as to warmth and moisture.

By the plan proposed, however, complete control is maintained over the direction and velocity of the entire mass of air which fills the hall.

Messrs. Shedd and Edson, in their report on ventilation to a committee of the Massachusetts house of representatives, dated January 1, 1865, remark in regard to this as follows:

"As regards the manner of applying the power to effect the change of air, it is sometimes applied to the exhaustion of the foul air, and sometimes to the supply of the fresh air. Either way is effectual in a degree, but neither alone accomplishes quite all

that is to be desired. Forcing the fresh air in abundantly will drive out the air already in the hall at every outlet, and it is essential for security against the intrusion of cold currents through cracks and doorways. But it will drive out mainly at the easiest outlets, and some of the most important may be neglected, because of being out of the easiest way for the air to pass. The only sure way to get the air out just where you want it to go out, is to apply an exhausting force at the outlets to guide and assist the expelling force. The filling method is called the plenum method, and the exhausting the vacuum method. Much has been said about the superiority, for working vigor, of air in a plenum, or over-pressure condition. There is no doubt of the fact that under a high atmospheric pressure a man has greater power than under a low pressure. But the amount of superior pressure that can be obtained in a common hall is very slight, and can hardly have a perceptible effect. A nearly even balance of the filling and exhausting forces, making the in-door barometer about the same as the out-door, but with the filling force enough in excess to keep out all air seeking to enter without leave, is the most economical and satisfactory condition to obtain."

PLACE OF OBTAINING THE AIR.

In the report of Senator Buckalew to the Senate from the Joint Select Committee on Ventilation, made February 20, 1865, he says:

"The air for ventilating the halls is now taken from the levels of the terraces, between the wings and the old Capitol building, on the western side. To these situations much dust and other impurities are carried by the action of the winds, subjected to the influence of eddies, and taken with the air through the ventilating passages into the halls. And in warm weather, the terraces and adjoining walls, becoming heated, affect very considerably the temperature of the air obtained. Reference upon this point of the inquiry is made to the testimony of Dr. Antisell, and Mr. Forney, the engineer in charge of the ventilation of the House of Representatives. It is manifest that the air introduced into the halls should be obtained from places not subject to the accumulation of impurities, or to the undue production of heat."

The architect of the Capitol extension, Mr. Edward Clark, in a report dated November 1, 1866, states:

"Objections have been made to the fresh air source. The present inlets are near the angles of the wings and connecting corridors, and are liable at all times to admit dust, and oftentimes do admit other impurities thrown from the windows. Besides, the air at this place has an increased temperature in summer, obtained from the reflection from the heated walls and pavement.

"In order to obtain a purer, and, in summer, a cooler supply of air, it is proposed to construct an underground duct, opening in the eastern grounds, which opening could be made an ornamental feature by placing a fountain in its center. The jets and overflow would assist in cooling the air and to rid it of any mechanical impurities with which it might be charged. A separate duct and fountain will be required for each wing."

Mr. Charles F. Anderson, an architect and civil engineer, in a report to the Joint Select Committee on Ventilation, &c., says that the present plan "receives the exterior air under the ground floor from off the surface of the overheated and dusty terraces, furnishing much of the bad air from beneath, carried to its surface by evaporation and side currents of air from the ground; and this air is also tainted with much of the odors caused by the machinery near which it passes."

This gentleman proposed the erection of high towers to serve as openings to the inlet ducts, but as it is well known that the dust on a windy day rises as high as the top of the dome, these would not be an efficient remedy.

I would propose a modification of the plan of Mr. Clark, the architect, as already quoted from his report.

I would place the mouth of the tunnel in the western instead of the eastern park, partly because it is nearer, but more because the prevailing winds are from that direction, and the foulness from all the horses, which are numerous in the vicinity of the eastern park, would be avoided.

At a distance of 194 feet from the western front of the House wing there is a beautiful spot, completely canopied with the boughs of ten or twelve trees, which stand in a circle of about 50 feet in diameter. In the center of this circle I would make an opening 25 feet diameter and 24 feet deep. Over this I would erect a substantial wire screen, 25 feet diameter at the base by 22 feet in height, and similar in form to the Capitol dome. It would be made of quarter-inch wire, of pure block tin, that it might be durable, and always clean and healthy. The meshes would be of about 1¼ inches. Over the top of this there would be a revolving fountain with four jets, each of which would project downward in an oblique direction, and throw a small stream of water with force upon the wire work of the screen.

It will be readily understood that this arrangement would keep every wire covered with an envelope of clean water, against which the entering air would have to rub in

passing in. This forcible contact would transfer the dust from the air to the water. The muddy water would fall to the bottom of the duct and pass away by the drain through an appropriate trap.

From the bottom of this vertical opening a tunnel would extend horizontally to beneath the blowers in the center of the cellar; and these blowers are so inclosed as to draw their air wholly from this source. The tunnel is 15 feet in diameter, and the top of it passes 16 feet below the lowest point of the foundations of the building. Its horizontal length would be about 300 feet. The entire tunnel would be lined with brick and cemented in the most substantial manner. Around the inlet screen there would be a granite coping and marble curb, to correspond with the fountains in the same park, except that the curb would be 4½ feet high, in order that the air drawn in should come from an upward direction. This arrangement is clearly shown in Plate IV. The valve for supplying the fountain would be situated in the engine-room.

Thus the air would be drawn down through the foliage of the trees into a clean passage, coming in contact afterward with nothing which could vitiate its purity until it had performed its functions of ventilation.

II. WARMING AND MOISTENING THE AIR IN COLD WEATHER.

There are three methods in common use for warming the air of ventilation in buildings: 1st, by passing it over iron surfaces which are heated directly with fire and the products of combustion; 2d, by passing it over iron pipes filled with steam; and 3d, by passing it over iron pipes filled with hot water. The first of these methods is considered as so highly objectionable as to be entirely discarded in first-class buildings. When air is brought in contact with highly heated iron surfaces, an unpleasant odor is given to it, so that people say it is burnt, and there is a general belief that it is very unhealthy air to breathe.

The employment of steam pipes is regarded as an amelioration of the above difficulty, as their temperature is not so elevated; and hot water is used in preference to steam in order more fully to secure the same end.

In the examination of Mr. Goldsworth Gurney before a committee of the British House of Commons, March 31, 1854, he testified as follows upon this point:

"Question 31. Do you think that the offensive smell may arise in any degree from the use of metal pipes? There is sometimes what is called a 'ferruginous odor' produced from iron pipes, but I believe not much in the present case; burnt air is the great source—the decomposition of small particles of animal matter which always float about in the amosphere. This question has been settled by French philosophers many years ago: it is not from the decomposition of the nitrogen and oxygen, but from the decomposition of those ammoniacal matters which are always found more or less in the atmosphere.

"Question 32. Would you be disposed to recommend any other material than iron for the warming pipes? I should prefer zinc; it is clean, a good conductor, and radiates heat well."

My own opinion is that the rusty surface of the iron imparts most of the offensiveness experienced, and that, therefore, the term "ferruginous odor" is correct, and as it is impossible to employ iron pipes for this purpose without their surfaces soon becoming rusty, the true remedy is to supply a more cleanly metal, as recommended by Mr. Gurney. That gentleman afterward, in rearranging the ventilating apparatus of the houses of Parliament, employed surfaces of sheet zinc heated with hot water. The improvement in cleanliness by exchanging zinc warming surfaces for iron was very great, but an equal improvement over the zinc surfaces can be made by the employment of pure block-tin tubes. This is superior to all the useful metals in its power to resist atmospheric influences. In this respect, indeed, it is fully equal to silver. It is a good conductor of heat; and though its bright surface would prevent its radiating heat well, as claimed by Mr. Gurney for zinc, this is unimportant, as air is not warmed by the heat of radiation, but only by direct contact with bodies warmer than itself.

Recent improvements in the mechanic arts have brought tin-encased lead pipe and solid block-tin pipe largely into use for conveying water in dwellings; its cleanliness and healthfulness strongly recommending it.

I would therefore employ pure block-tin tubes, filled with hot water, for warming the air. This would not only warm the air without imparting any odor whatever to it when the apparatus was new, but would continue to do so for a great many years after zinc had become entirely coated with its oxide, or iron had rusted through and through and been many times renewed.

In Plates I and II of the illustrations there will be observed five congeries of tubes in each of the two great air-ducts in the foundation story. These marked *h* are for warming the air. Each tube is 10 feet long by 1¼ inches outside diameter; they are secured into brass tube-heads in the same manner as in the surface condenser of a marine engine. They open at each end into steam-tight chambers, or chests. Into the upper of these I would introduce steam from the boilers; and from the lower I

would draw off the water by appropriate pipes, the valves of which would be situated in the engine-room.

It will be understood that with this arrangement the apparatus would be a steam heater, if the extent of the tubular surface was limited to the amount necessary to warm the air by the condensation of the steam only, but that if the surface is enlarged to the amount required to warm the air with hot water, the steam will be condensed in the upper chambers and the upper ends of the tubes, hot water filling the remainder of the tubes and the lower chambers. A valve in the pipe through which the water flows away would control the rapidity with which it was drawn off and consequently its temperature. In ordinarily cold weather this would be hot-water warming apparatus, but upon any extremely cold day it would become a steam-heating apparatus as the attendant opened the regulating valve in the drain pipe.

To decide upon the amount of warming tube-surface necessary, it is first requisite to consider the subject of

MOISTENING THE AIR.

Water pervades the entire human system; considered mechanically, it performs the functions of a lubricant to all its parts. The ligaments and muscles move freely in their places because every fiber of them is coated with water. The skin and hair are soft and pliable for the same reason. In all mechanism the lubricant must be constantly renewed, as the surfaces it lubricates are always wearing away, the particles worn off being absorbed by the lubricant and flowing away with it. In the case of the human body we find the lubricating water, the supply of which is kept up by our daily food and drink, working its way gradually to the surface through the skin and lungs to the air, where it arrives loaded with worn-out particles of our animal nature, and into which it evaporates.

Now the rapidity with which water of a given temperature will evaporate into air in a state of rest is dependent entirely upon how far the condition of the air in regard to moisture is removed from the point of saturation. And in the case of the evaporation from our bodies, if it is too rapid, the skin becomes too dry, and this again induces too rapid a flow of the water within the system toward the surface, making us uncomfortable, and sometimes ill.

Again: the process of evaporation is a cooling one to the surface from which the evaporation takes place. This is explained by the absorption of the latent heat which occurres upon the conversion of a liquid into a vapor. When, therefore, the evaporation is too rapid we are uncomfortably cold, even though the temperature of the air may be sufficiently high.

On the other hand, if the evaporation is too sluggish, the flow of water toward the surface is retarded, and we are made uncomfortable and sometimes ill in another way; also, if the air is of the proper temperature we are uncomfortably warm, the general feeling being described by the term "muggy."

It is highly important, therefore, that the condition of the air as to moisture should be maintained, in any system of ventilation, at that which is the most comfortable and healthful; indeed, that which is the most comfortable is the most healthful.

Most writers upon the subject of the ventilation of large assemblages say that it is impossible to adjust the condition of the air so that all will be comfortable. That persons whose blood has become thinned by age or illness, or who are naturally thin and cool-blooded, require a higher temperature than those who are young, strong, and full-blooded. Also, that in an assemblage where, as in this case, the same person sometimes sits during the entire session of the day without moving or speaking, and at others exerts himself strenuously in a vigorous speech, he is either too cold or too warm, accordingly as he sits still or exerts himself.

My observations and studies upon this subject, however, lead me to the conclusion that if the degrees of heat and moisture are both properly tempered, *i. e.*, each brought to the average of the most comfortable for all, there will be no complaint. The aged and feeble may feel cooler than the young and strong, but they will be comfortably, not uncomfortably cool. Also, when a member sits quietly in his seat all day he will be cooler than when he exercises, but then it will be a comfortable coolness; and when he has greatly exerted himself in an extended speech, in which his deep interest may have led him to become excited, although he will feel warm, it will not be an uncomfortable warmth. Indeed, the question is not whether persons feel warm or cool, but whether they are comfortably or uncomfortably so.

As a general rule, the only point which receives proper attention in the ventilation of large assemblages is that of the temperature. The air is almost always too moist or too dry—generally the latter in cool weather, even if pure—so that the degree of comfort experienced by each is dependent upon his strength and health. It does not hurt a young, strong, healthy person so much to draw the water out of him too rapidly or too sluggishly as it does an old, feeble, or sick person. But the health and strength of the most vigorous man is gradually undermined by any extended persistence in living

in air which has either a great excess or deficiency of moisture, and one of the great difficulties about it is, that in nine cases out of ten he does not know why his health has failed.

I would, therefore, provide for controlling the amount of moisture in the air so that the exact degree of it desired should be maintained with the same precision as the temperature.

The eminent Professor Henry, of the Smithsonian Institution, in a report on the warming and ventilating the Capitol, dated May 4, 1866, remarks upon this point:

"It is evident that the great object of warming and ventilating an apartment in the winter season is to supply it with pure air of the same degree of temperature and the same amount of moisture as that of an open space in a pleasant time in summer. To fully attain this object is a very difficult matter, but that system of warming and ventilation is certainly the best which approximates the nearest to this desirable condition. The heating of the air and preserving it at the desired temperature is the simplest part of the problem; to remove the impure air and to supply its place with fresh air without giving rise to unpleasant currents and unequal temperature is more difficult: to supply the proper quantity of moisture and to prevent its condensation is attended with still greater difficulty, particularly when apartments containing a large number of persons are to be thoroughly ventilated. This part of the general problem is, in my opinion, an essential element of proper ventilation, although it has hitherto received comparatively but little attention in this country.

"The idea is entertained by some that because the heating of a large volume of air to the required temperature of the room does not abstract the aqueous vapor which it contains, that hence evaporation from a surface of water is not required to render such air salubrious. It should, however, be recollected that when the external air is, say, at the temperature of zero, all of its aqueous vapor has been condensed, with the exception of an almost imperceptible quantity, and when this desiccated air is afterward heated to a temperature of 70°, its *capacity*, so to speak, for vapor, is so much increased that moisture exhales into it with great energy from all bodies from which it can be evaporated. A rapid current of ventilation of air in this condition constitutes an artificial sirocco. * * * It is true that the supply of the necessary amount of moisture will increase the cost of heating and ventilation, but this is a consideration which cannot, in most cases, be allowed to weigh against health and comfort."

From the report of Dr. Wetherill on the warming and ventilation of the Capitol, to which reference has already been made, I extract the following remarks:

"For an atmosphere which shall be salubrious to the inmates of an apartment, the hygrometric condition of the air is as important as its freedom from poisonous or deleterious gases.

* * * * * * *

"The evaporation of water from the body is intimately connected with health. The sudoriparous glands, which are constantly secreting their liquid, have a length of tubing which has been estimated at twenty-eight miles. The secretion takes place so gradually that the water ordinarily evaporates, as insensible perspiration, as soon as it reaches the exterior surface of the skin.

"During severe exercise, exposure to great heat, in some diseases, or when the evaporation is hindered by an impermeable covering, the secretion collects upon the exterior of the body in drops of sensible perspiration.

"The total average loss by the lungs and skin in twenty-four hours is almost $3\frac{1}{2}$ pounds of water, of which somewhat more than two-thirds, say $2\frac{1}{2}$ pounds, are furnished by the skin. Of these $2\frac{1}{2}$ pounds only one-sixth is furnished by the vital process of secretion by the sweat glands; for the greater part of the moisture transudes through the skin by simple evaporation. The cutaneous and urinary excretions are, as is well known, vicarious. The evaporation from the skin regulates the animal heat, the body being in analogous condition to those porous earthen jars in which the inhabitants of tropical climates cool water by the evaporation of that portion which exudes to the surface of the vessel.

"The estimated loss of heat to the body by evaporation, per minute, is sufficient to raise half a pint of water from the freezing to the boiling temperature.

"For health, the body must evaporate a quantity of water within certain limits. The amount evaporated is influenced by the hygrometric condition of the air, and by the state of the body itself. The evaporation is increased by muscular action and by a dry atmosphere; it is diminished by repose and by a moist air.

"If the functions of the skin are interrupted, certain diseases are manifested. Among these are affections of the throat, catarrh—passing into acute bronchitis—pulmonary consumption, pericarditis, inflammation of the stomach and bowels, dyspepsia, rheumatism, gout, and fevers.

* * * * * * * *

"The rapidity of the evaporation of the body depends *principally* upon the low rela-

tive humidity of the air at a high temperature, and upon the maintenance of this condition in the neighborhood of the body by the action of currents of air. Thus, with too great dryness of the air, particularly at an elevated temperature, and especially if it pass rapidly over the body, there will be a greater degree of evaporation than is consistent with health. On the other hand, in an atmosphere saturated with moisture, the evaporation from the body would be reduced to a minimum, and would be practically nothing in such air having the same temperature as the body. Although we may bear with impunity these extremes for a short period, a persistence in such conditions would be fraught with danger.

* * * * * * * *

"It is certain that the hydration of the air will involve, in the winter, a considerable expenditure of fuel for a powerful ventilation; but the hydration is as necessary to health and comfort as the warmth."

Dr. Youmans, in his Handbook of Social Science, page 308, says:

"Air changed in temperature by warming, without increased moisture, is apt to produce unpleasant feelings and painful sensations in the chest, which are often attributed to too great heat. In very dry air the insensible perspiration will be increased, &c. The objection lies against *heated* air, no matter how heated. Stoves and air furnaces, with their red-hot surfaces, are undoubtedly worse for the air than hot-water apparatus, which never scorch it; yet the latter may pour into our apartments a withering blast of air at 150°, which may be potent for mischief. The only way that hot air can be made healthful and desirable is by an effectual plan of artificial evaporation."

In the report of Senator Buckalew, to which I have before alluded, he says, page 4:

"It follows that the dry and warmed air for supplying rooms of great magnitude must be passed over an evaporating surface of great extent, in case that mode of hydrating it be adopted. Doubtless warming the water would increase the efficiency of the plan. Dr. Antisell recommends spray, or jets of water, thrown into the air at a right angle to its current, which would, no doubt, be an effective and satisfactory mode of accomplishing the object where the necessary facilities can be established, among which space is indispensable. The objections to the use of steam on an extensive scale for hydration are the production of noise, and, as alleged, of odor, and its imperfect dissolution in the air before entering the chamber. It passes on with the current of air for some time before it becomes dissolved and incorporated with it, and moisture is deposited upon all surfaces with which the volume of air comes in contact. There is no arrangement for introducing steam into the air passing to the halls, but it was provided for the air directed to the committee rooms and passages. The plan was not found to work well, and has not been in practice."

Mr. Lewis W. Leeds, the consulting engineer of ventilation and heating for United States Treasury Department, &c., in a report to the Hon. John Covode, on the ventilation of the House of Representatives, dated January 13, 1868, says upon this point:

"There seems to be an entire unanimity among all parties as to the necessity for additional moisture. This I think of much importance. I however doubt the propriety of allowing the steam to be discharged directly into the fresh-air chambers. There is often an unpleasant smell from escaping steam, and more frequently from the air driven from steam pipes as the steam enters."

The plan I would propose for moistening the air is, to place in the air-ducts in the cellar, just beyond the heating pipes, a system of water pipes, as shown at *m m* in Plates I, II, and V. It will be observed that there are ten pipes, each 20 feet long, lying horizontally, lengthwise of the duct, and distributed throughout its cross-section so as to equally divide it up. In each of these ten pipes there would be a great number of minute holes extending all around the circumference and throughout the length of the pipe. The water driven into these pipes with force would spin out of these holes radially from each pipe, filling the entire duct with a fine shower. The air passing through this shower would be moistened, and a valve in the engine-room, regulating the force with which the water was driven into the pipes, would determine the degree of moisture at which the air should be delivered into the hall.

There are several methods in common use for designating the degree of moisture of the air, viz:

1. The number of grains in weight of water per cubic foot of air.
2. The tension of the vapor in height of a mercurial column.
3. The depth of water there would be on the ground if all the vapor in the air should be suddenly condensed and fall.
4. The "break," or difference between the wet and dry bulb thermometers.
5. The temperature of the "dew-point."
6. The "relative humidity," or per centum which the amount of moisture in the air is of that necessary to saturate it at the same temperature.

The last of these is the most popular method, because it appears to be the general

opinion that this expression should be uniform for all temperatures, to render the air comfortable and healthy to live in. There does not, however, appear to have been any very exact determination of what this should be; but with a temperature of 65°, a strong, healthy person is not uncomfortable when it ranges above 50 and below 80; but in the course of some careful observations of the effect upon delicate persons in feeble health, I have found them commence to complain when it went as low as 60, and again when it went up to 70; the complaint being, however, that it was too cool with the former degree of moisture, and too warm with the latter, although the dry-bulb thermometer continued at 65°. With a temperature of 65° and a relative humidity of 65°, however, I have heard no complaints; and I find that, personally, I can sit quiet or exercise in air of that condition with great comfort, with indoor winter clothing.

With the entire ventilating apparatus arranged as I would propose, these points can be fixed upon, and afterward maintained as may be found desirable by experience; but I will assume the above temperature and degree of moisture as the base of my calculations for the amount of surface required for the warming tubes.

A relative humidity of 65° with a temperature of 65° corresponds with—

4½ grains of water per cubic foot of air,
A tension of $\frac{1}{10}$ of an inch of mercury,
A depth of 5¼ inches of water on the earth,
A break between the wet and dry bulb thermometers of 5½°, and
A dew-point of 52°.

To exhibit the increased capacity of the air for dissolving the vapor of water, as its temperature is elevated, the following table is extracted from one by Guyot, quoted by Dr. Wetherill in his report:

Temperature of air.	Vapor in grains per cubic foot.	Temperature of air.	Vapor in grains per cubic foot.
0°	0.545	55°	4.860
5	0.678	60	5.756
10	0.841	65	6.795
20	1.298	70	7.992
30	1.968	75	9.372
32	2.126	80	10.949
40	2.862	85	12.756
45	3.426	90	14.810
50	4.089	95	17.145

The temperature of the external air in Washington is so seldom below 20°, even in cold winters, that I would limit the surface of the warming tubes to an ability to warm the air entirely with hot water from that degree of coldness, and for colder weather would allow it to become a steam-heating instead of a water-heating apparatus, as already explained.

The lowest degree of humidity of the external air reported by Dr. Wetherill, as found in his experiments, was 1.11 grains per cubic foot. I will assume one grain for the base of calculation. There will then have to be added 3½ grains per cubic foot to give it a relative humidity of 65 when at a temperature of 65°, and as there are 7,000 troy grains in one pound avoirdupois, 80,000 cubic feet of air will require—

$$\frac{80000 \times 3\frac{1}{2}}{7000} = 40 \text{ pounds of water per minute.}$$

The temperature of the water would probably be about 40°. This would have to be warmed up to a temperature of 65°, and be supplied in addition with the latent heat necessary to form it into vapor at that temperature.

To ascertain how much the air must be superheated for this purpose—

Let s = specific heat of air as compared with water = 0.2669
v = volume of air in cubic feet = 80,000
w = weight of air in pounds per cubic feet = 0.075
t = temperature from which water is raised = 40°
t' = temperature to which water is raised = 65°
l = latent heat of steam at that temperature = 1070°
W = weight of water to be absorbed in pounds = 40
x = number of degrees the air must be heated above 65°, in order that it may be at that temperature after it has dissolved the moisture.

Then,

$$\frac{W\ (l + t' - t)}{s\ v\ w} = x = 27°.$$

The temperature to which the air must be raised under the above conditions of the weather before it is moistened would, therefore, be—

$$65^\circ + 27^\circ = 92^\circ.$$

Now, to determine the extent of surface required for the warming tubes—

Let P = temperature of water in tubes.. = 192°
T = temperature of air after heating = 92°
t = temperature of external air.... = 20°
C = volume of air in cubic feet...... = 80,000
S = surface of tubes in square feet.

Then,

$$.0045\ C\ \frac{(P - t)\quad(T - t)}{P - T} = S;\ \text{and}\ S \doteq 44{,}582\ \text{square feet.}$$

Each tube, being 10 feet long by 1¼ inches diameter, would have a surface of 2.9 square feet. There would, therefore, be required 15,373 tubes. I have divided them into eight several congeries for convenience of construction, with 1,922 tubes in each.

In some seasons of the year there will be days when the external air will be all right as to the temperature, but will be deficient in moisture. In such event both the heating and moistening apparatus would have to be employed, as we have seen in the foregoing that the operation of moistening the air is a cooling one. When, however, the heat is a little in excess and the moisture correspondingly deficient, the moistening apparatus would serve both as a cooler and hydrator, and it is only when the weather happens to be in that exact state that the very prevalent idea that the air may be cooled by jets of water is applicable. When the air is too moist as well as too warm, such jets would add greatly to the discomfort experienced. When the relative humidity is in excess in the external air and the temperature too low, merely heating the air may correct both difficulties. I would arrange indicators in the engine-room, such that the engineer would be able to see, at all times, the exact condition of the air in the hall as to temperature and moisture; and then I would so arrange the controlling valves of the entire apparatus that as he looked at the indications he could add or remove moisture, elevate or depress the temperature at will and at once.

When a person enters a building on a cold day in winter, especially if he has been riding, he will invariably repair to a fire to warm himself, if there is one. The most grateful fire one can enjoy, under such circumstances, is one that presents a clear, cheerful blaze. Good dry hickory wood in an open fireplace, having burned long enough to be in a glowing state of combustion throughout, is, I believe, every one's *beau ideal* of a pleasant fire. Such fires might be supplied to the cloak-rooms, but the objection to them would be the constant attention they would require to keep them always in full blaze. Anything less than that would be unsatisfactory, as, if a member came in nearly frozen he would get warm by the general warmth of the hall before a fresh fire could be brought to the necessary heat-giving condition.

The gas fireplaces which have been introduced into the residences of some of the wealthier citizens of New York, within the past two years, fulfill all the requirements of the case in the most complete and elegant manner. When not required, the gas can be turned down to an ignition blaze, and the moment any one or more persons wish to enjoy an especial warmth, they have only to turn on the gas, when there instantly occurs the most efficient and cheerful fire it is possible to imagine.

I would place two of these in each of the four cloak-rooms.

III. COOLING AND DRYING THE AIR IN HOT WEATHER.

To reduce the temperature and moisture of the air of ventilation in the hot weather in summer is a much more expensive operation than warming and moistening it in cold weather. But, in the warm climate of Washington, the midsummer session is always dreaded by members of Congress. During the hot season of last July, the House adjourned on two different occasions at an exceptionally early hour, because it was beyond the limits of physical endurance for the reporters to continue their labors longer in the fervid heat. Members were compelled to frequently leave their places and seek temporary relief in some breezy window. Some members, indeed, refrained entirely from appearing in their seats on those hot days. Of course the oppression was much increased by the impurity of the air, owing to the faulty ventilation; but there can be no doubt that the comfort and health of the members can be greatly improved by cooling the air when it is so excessively hot, though it be pure and plentiful; and that those composing so important a body as the House of Representatives should not be made uncomfortable and ill to an extent which every one recognizes as seriously interfering with the business they meet to perform, will, I think, be evident to all; even though the expense of reducing the temperature be greater than it has heretofore been customary to incur for any ventilating process.

Some attempts have already been made in this direction, but, like all the features of

the present system, the means employed were entirely inadequate to accomplish the end proposed. Thus, 2 tons of ice were melted in the air-duct leading to the hall during each day of about 5 hours, say 800 pounds per hour. The quantity of air passing through the duct, with the blowing-engine running at its usual speed of 42 revolutions per minute, as carefully measured by myself, was 24,300 cubic feet.

The temperature of the ice was, say	25°
That of the water of condensation was, say	60°
The latent heat of ice is	140°

To determine how much the air would be cooled by melting the ice—

Let t = temperature of the ice = 25°
t' = temperature of the water of condensation = 60°
l = latent heat of ice = 140°
s = specific heat of air = 0.2669
w = weight of air per cubic foot = 0.075
v = volume of air in cubic feet = 24,300
W = weight of ice melted per minute = $13\frac{1}{3}$
x = number of degrees the air would be cooled by the melting of the ice.

Then,

$$\frac{W\,(l + t' - t)}{s\,w\,v} = x = 4\tfrac{3}{4}°$$

As, however, the air thrown in by the present blower is mixed up with that which flows into the hall through the open doors, the temperature of the hall is only reduced about one degree by the melting ice.

The greatest absolute amount of moisture Dr. Wetherill found in the air at the Capitol, in his experiments, was 8.93 grains per cubic foot; and this was during the prevalence of a rain-storm.

The temperature seldom rises above 95°, but it reaches that point often enough to establish the propriety of assuming that as the maximum.

If now we suppose the temperature to be 95°, and the moisture in the air at 9 grains per cubic foot, and we wish to reduce the temperature to 75°, and not permit the relative humidity to rise above 65, we must abstract three grains of water from each cubic foot, or—

$$\frac{80{,}000 \times 3}{7{,}000} = 34.3 \text{ pounds from the whole quantity per minute.}$$

At the moment of the condensation of this water from a vapor into a liquid, its latent heat is given out into the air; so that removing the vapor is a warming process, as has already been shown that the addition of it is a cooling one.

The additional extent which the air must be cooled to compensate for this latent heat of the vapor is expressed by the formula—

$$x = \frac{W\,l}{s\,v\,w}$$

Where W = the weight of water in pounds = 34.3
l = latent heat of the vapor = 1091°
s = specific heat of air = 0.2669
v = volume of air in cubic feet = 80,000
w = weight of air per cubic foot = 0.075
x = the number of degrees the air will be warmed by the condensation of the vapor.

With the above values,

$$x = 24°$$

The entire cooling effect must, therefore, be equivalent to 44°.

This would require 24,000 pounds of ice to be melted per hour, or, say, 60 tons per daily session of five hours.

Coal is cheaper than ice per ton, is more conveniently stored and handled, and *one-sixth* of the above quantity burned in the furnace of a steam-boiler will produce, through the medium of appropriate mechanism, an equal cooling effect upon the air. I would, therefore, discard the use of ice and employ steam-power instead.

Machines are operated by the steam-engine for the manufacture of ice, which produce cold by pumping off the vapor of sulphuric ether, or of the bisulphide of carbon; these liquids vaporizing rapidly at low temperatures if the pressure of the superincumbent atmosphere be removed, but the employment of such substances would be inadmissible in cooling the air for ventilation, as a slight leak in even one of the many tubes it is necessary to employ in such mechanism would impair the purity of the air to a decidedly sensible and objectionable extent.

I would, therefore, employ the steam-power to drive air-pumps to compress a portion of the air, making it hot, and while it was under this pressure cool it down to the ordinary temperature by passing it through tubes surrounded by flowing water; employing an apparatus for this purpose precisely like the surface-condenser of a steam-engine. This compressed air would then be conveyed to the duct through which the blowers were driving that which did not pass through the pumps, where it would be permitted to expand again to the ordinary atmospheric pressure. This expansion would be a cooling process exactly corresponding in extent to the heating one the air underwent when it was compressed: and by mixing this excessively cold air with the warm air from the blowers, the whole would be brought to the desired temperature.

It is mechanically convenient, in a machine of this kind, to compress two volumes of air into one in the pumps. To learn how much such an amount of compression would elevate the temperature, a formula is given by Peclét in his *Traité de La Chaleur, tome III, p.* 10, as follows:

Let θ = temperature before compression, (centigrade.)
d = density before compression.
θ' = temperature after compression.
d' = density after compression.

Then,

$$\theta' = (274 + \theta)\left(\frac{d'}{d}\right)^{0.42} - 274$$

In this case,

$$\theta = 35^\circ\ (= 95\ \text{Fahr.})$$
$$d = 1$$
$$d' = 2$$

and consequently,

$$\theta' = 139.44^\circ\ \text{cent., or } 283^\circ\ \text{Fahr.}$$

and the elevation of the temperature would be 188° Fahr.

When air is heated in a confined space its pressure is increased $\frac{1}{480}$ part with each additional degree. The pressure of the atmosphere being 14.7 pounds per square inch, the pressure upon the pump pistons during the last half of the stroke would be,

$$14.7 + \left(\frac{188}{48} \times 14.7\right) = 20.46\ \text{pounds per square inch.}$$

Let us say that we will maintain a pressure in our condensed-air cooler of 20 pounds per square inch.

To find how cold the air will be after its expansion, we have—

$$\frac{\theta' + 274}{\left(\frac{d'}{d}\right)^{0\ 42}} - 274$$

The temperature of the Georgetown water during the hottest weather in summer is about 70°. As I would arrange the cooler so that there would be reverse currents of cold water and hot air, the latter would be cooled down to say 75°, which corresponds with 23.89° centigrade.

As the heat was abstracted from the air it would be further condensed $\frac{1}{480}$ part with the departure of each additional degree, the pressure being maintained: hence we would have—

$$\theta' = 23.89$$
$$d = 1$$
$$d' = \frac{14.7 + 20}{14.7} = 2.36$$

Whence,

$$\theta = -66.12^\circ\ \text{cent., or } -87^\circ\ \text{Fahr.}$$

This would be a reduction from its original temperature of 182°.

This being slightly more than four times the amount of cooling force, it is necessary to apply to the whole quantity of air furnished one-fourth of that amount, or 20,000 cubic feet will require to be passed through the pumps.

Allowing 10 per centum for loss, the dimensions of the air-pumps will require to be as follows:

Number of pumps	2
Diameter of pistons	65 inches.
Stroke of pistons	6 feet.
Double strokes per minute	40

As the mean resisting pressure will be 12.4 pounds per square inch, the net power required to work them will be 1,200 horses. Allowing 10 per cent. for friction of engine and pumps, and we have 1,320 horses as the gross effective power of the engines. I would attach the steam and pump pistons to the same rods; with this arrangement, the steam-cylinders would have to be 45 inches diameter. I would employ a steam pressure of 40 pounds per square inch, and cut off at one-fourth from the commencement. A surface condenser would be attached, and the mean gross effective steam pressure would be 29 pounds per square inch. This cooling engine is shown in Plates I, II, and III of the illustrations.

If the cold air was simply conveyed to the air-duct and mixed with the warm air from the blowers, it would be cooled down below the desired temperature, and a portion of the moisture it is desirable to abstract would be condensed in the form of a fog and carried along with the air into the hall, which would thus be filled with a cold, damp air, highly objectionable. It is necessary, therefore, to have the cold air introduced in a peculiar manner, such that not only may the moisture be abstracted, but that the exact amount removed may be subject of convenient and easy regulation by the engineer in the engine-room. The character of this regulation must necessarily be that the power exerted by the engine shall determine the extent of the cooling force, and that the amount of this which shall be devoted to reducing the temperature of the air, and that which is devoted to abstracting the moisture, shall be subject to a regulating lever, or hand-wheel; so that if the engineer moves this in one direction the air will be made cooler and more moist, and if in the other it is made warmer and drier, the cooling engine continuing to run at the same rate.

To accomplish this, I would erect in each of the two cooling and drying chambers of the air-ducts a congeries of tubes somewhat similar to those employed for warming the air in cold weather, (marked *d* in the illustrations;) only I would have an additional chamber, or chest, at mid-height, so that there would be, in fact, two systems of tubes, one above the other; in other words, it would be two stories high. Now, in the two upper chambers I would have openings in the bottom in all the spaces between the rows of tubes; these openings controlled by valves, and the valves appropriately connected with hand-levers or wheels in the engine-room; there being one for a system of valves which would control the openings in every third space between the rows, and one for those in the remaining spaces. The aggregate area of the openings in the lesser system should equal the area of the pipe which brings the compressed air from the cooling engine; those in the other spaces, being of the same dimensions, would have in the aggregate twice this area. Then the compressed air should be conveyed by a pipe from the cooling engine to the lowest chamber; thence it would flow upward through the tubes into the upper chambers, then downward through the openings into the spaces between the tubes. The operation of this arrangement would be as follows:

Let us imagine a condition of the external air such as has been assumed for a maximum performance of the cooling engine. In this case let the openings in two-thirds of the spaces betweeen the tubes be closed, and those in the remaining spaces be wide open; the area of the whole being such that it would require a pressure of 20 pounds per square inch to drive all the air supplied by the pumps through them. It will be perceived that the pressure throughout, from the pumps to the exit, will be 20 pounds per square inch, and that, therefore, the temperature will be maintained at 75° while the air passes through the tubes. As the compressed air pours down between the two rows of tubes and expands to the ordinary atmospheric pressure, its temperature will fall so suddenly that the moisture within it will be condensed and part of it frozen into minute hail. The main portion of the air from the blowers will pass through the remaining spaces between the tubes; and as they are only one-eighth of an inch apart in the rows, they form, in effect, walls of separation between the warm and the cold air. A sufficient quantity of the air from the blowers will, however, pass into the cooled spaces to carry forward the hail-storm raging there, and as the hail and condensed moisture are carried along the narrow spaces they will come in contact with the surfaces of the tubes and be deposited upon them. The temperature of these will be too low to vaporize the moisture, but warm enough to melt the hail, and the water will run down them, as it does along the sides of an ice-water pitcher, to the bottom tube-sheet, whence it will pass off in proper drains prepared for it.

If the warm air issued from the drier with the same velocity as the cold, exactly one-third of the whole amount would be excessively cooled, and nearly all its moisture extracted; but the great velocity with which the compressed air will pour into the spaces between the tubes, having only to be changed in its direction by the horizontal current from the blowers, will flow out with considerably greater velocity than the warm air from the remaining spaces; so that something more than one-third of the moisture contained in the whole amount of air will be deposited upon the tubes and carried away. In the case under consideration, exactly one-third is the amount it is desired to extract. The necessary reduction will be made by slightly opening the valves in the remaining spaces; the immediate effect of which will be to cool down all the tubes by causing a partial expansion of the air within them, so that the warm air

will be cooled somewhat by coming in contact with the tubes, in addition to having some of the cold air mixed with it. This will lessen the extent to which the temperature will be reduced in the cold spaces, and, consequently, the amount of moisture which will be condensed and extracted.

If all the valves be fully opened, the air would, in this case, be delivered from the drier at a temperature of about 67°, and a relative humidity of 100°; the air would feel very cold and damp, but there would be no mist or fog, as all condensed moisture would be deposited upon the cold tubes, and the exact degree of humidity desired could be obtained by adjusting these valves: opening them would moisten and cool the air; closing them would dry and warm it.

When the cooling engine was not required to run at its full force, the first set of valves would require to be partially closed, when it was necessary to produce a large drying and a small cooling effect.

As the air issues from the drier it will be in vertical strata of cold dry and warm moist air, in the proper proportions, both with regard to temperature and moisture, to give the desired condition when they are mixed, which they will soon become as they pass along the duct.

When, however, the external air is of the right temperature, or not much above it, but is so damp that it must be dried, the resulting temperature of the mixture will be too low: in which event it must be warmed up to the desired point as it passes through the heater.

On the other hand, the external air may be so dry that when it is cooled down to the desired temperature it will still be too dry; when this occurs the moistening apparatus must be put in operation. Indeed, as has already been explained, it will sometimes happen that moistening the air will sufficiently cool it.

To enable the engineer in charge to control the condition of the air be delivered to the hall, I would arrange pipes about three inches in diameter and properly incased with a non-conductor of heat, from the inlet duct, from the tempering ducts just beyond the moisteners, and from the hall; leading them through a convenient place in the engine-room for observation to the suction openings in the blowers, which would cause a rapid flow of air through them, having the exact condition existing at the other ends of the pipes. Into each of these pipes, as they pass through the engine-room, I would insert the wet and dry bulbs of a hygroscope, which should plainly indicate the temperature and degree of moisture in the air passing through the pipes.

The method here recommended for drying the air when it is too moist, or when it is made so by reducing its temperature, is simply the adoption upon a small but sufficient scale of that employed by nature in effecting similar changes of weather.

Dr. Metcalf, in his incomparable work on caloric, vol. i, p. 267, and following, describes and explains the influences exerted by the vapor of water upon the atmosphere, and how it is added and removed. I quote from him as follows:

"As the phenomena of lightning have been universally known to be immediately connected with the production of rain, it becomes necessary to ascertain with certainty the cause of evaporation and condensation before attempting to solve the problem of atmospheric electricity.

"That caloric is the true and only cause of evaporation, or the formation of steam, is one of those self-evident propositions which would seem to require no proof. But to remove all doubts upon the subject the fact has been experimentally demonstrated by Dr. Dalton, to whom the science of chemistry and meteorology is so largely indebted.

"He put a little water in a dry glass flask with a thermometer in it, when he found that a small quantity of vapor was formed at 32° Fahrenheit. At 40° the amount was increased; at 50° it contained still more vapor; while at 60° the quantity was yet further augmented. He also found that when the temperature of the flask was suddenly reduced from 60° to 40° a portion of the vapor was converted into water, and that the quantity retaining the elastic form was precisely the same as when the temperature was originally at 40°.

"The above is a simple and beautiful representation of what is perpetually going on throughout the atmosphere and in the steam-engine.

"By another series of admirable experiments he ascertained that the quantity of water evaporated in a given time was exactly in proportion to the elastic force of vapor at the same temperature, whether formed in *vacuo* or under the pressure of the atmosphere, with this difference, that in the latter case the process goes on much more slowly because the atmosphere presents a mechanical impediment to its diffusion somewhat analogous to the obstruction of water by porous sand. From which he inferred that vapor is not chemically united with the air, as has been formerly supposed, but mechanically diffused through it, forming a distinct atmosphere of its own, the elastic force of which is always in proportion to temperature.

"At 0° he found the elastic force of vapor equal to the pressure .064 inch of mercury, that is, about one-fifteenth of an inch; at 32° it amounted to one-fifth of an inch; at 47° about one-third of an inch, or .339; at 59° .507, or one-half an inch; at 80° one inch; and at 90° 1.360. He also ascertained that the elastic force of vapor at 212° is equal

to the pressure of the whole atmosphere, or 30 inches of mercury. (Manchester Memoirs, vol. 5.)

"From the above experiments it follows that if the temperature of the earth were 80° from the equator to the poles, the quantity of vapor would be everywhere the same, and equal to about one-thirtieth of the average weight of the whole atmosphere; but that if its temperature were reduced from 80° to 59°, one-half of the vapor would be precipitated in the form of rain; if to 32°, four-fifths of it would be converted into snow; and if reduced to 0°, 14 out of 15 parts of the whole would descend to the earth in the form of ice, in obedience to that universal law of nature by which bodies cohere and tend toward a common center.

* * * * * *

"If at the temperature of 80° the atmosphere contains an amount of vapor equal to the pressure of only half an inch of mercury, while it is capable of sustaining twice that quantity, it will require a reduction of temperature below 59° to cause precipitation. Hence it is that the atmosphere often undergoes great reductions of temperature without producing rain. But when the air is full of vapor the process of evaporation is arrested; which explains why a cold, dry air is more favorable to evaporation than warm air that is already saturated, especially if the former be in a state of rapid motion.

"Dr. Dalton found that when boiling water was exposed to a current of air that carried off its vapor as fast as formed, vaporization went on a third faster than in a room where the air was still. Hence it is that the northeast and east winds, which in the west of Europe are generally dry, and far below the point of saturation, seldom condense the vapor of France and England; but, on the contrary, often re-dissolve the clouds already formed, producing clear weather. During summer, when the atmosphere has been for some time comparatively still, it is soon saturated with vapor, which is indicated by heavy dews and the formation of clouds termed *cumuli*, in which case the weather becomes hot and sultry, because the caloric which is usually carried off by evaporation and winds accumulates on the surface of the earth and heats the superincumbent air. Such a state of things generally forebodes an approaching thunder-storm.

"That the condensation of atmospheric vapor is owing to the abstraction of its caloric by colder currents of air is evident from the fact that in the tropical ocean, far from land, where the trade-wind blows steadily in one direction, and where the temperature seldom varies more than two or three degrees, there is less rain than in the vicinity of continents and large islands where currents of air of different temperatures frequently meet.

"In the great desert of Sahara there is scarcely any rain, because the wind blowing over it is generally in the same direction, while the vapor transported by it from the ocean is still further rarefied by the intense heat reflected from the scorching sands, where there are no mountains to arrest its progress. There are also long droughts in Egypt, Palestine, New Holland, and many other parts of the world, where the winds blow long in one direction without encountering colder currents. During summer in the United States the atmosphere is often so much heated that the vapor brought from the ocean by southern winds is not condensed for several weeks, and sometimes two months, but is further expanded, until it becomes saturated, or meets with a current from the northern points of the compass, when thunder-gusts follow.

"When I come to treat of winds it will be shown that the most extensive falls of rain in the middle latitudes are produced by the meeting of immense masses of air from opposite quarters of different temperatures, as during the equinoctial floods and storms. When both contain as much vapor as they can support at their respective temperatures, the amount of precipitation is of course the greatest.

* * * * * * *

"There is nothing more admirable in the great drama of nature than the process of evaporation and condensation, by which all the waters of lakes, rivers, and fountains are elevated from the ocean, transported over continents and islands, precipitated by polar currents, and distributed in the form of great natural shower-baths over the dry land.

* * * * * * *

"By a careful analysis of the phenomena, it becomes self-evident that, *if caloric be the true and only cause of evaporation, condensation and precipitation can be effected only by the evolution of the same agent.* During winter the quantity and elastic force of vapor in the atmosphere are comparatively low in the middle latitudes, where it is condensed gradually on meeting with colder air. During spring evaporation augments with increase of temperature, when masses of warm and cold air often meet, causing frequent showers of rain and sometimes of hail, still without much thunder and lightning. But during summer, when the temperature becomes tropical and the atmosphere saturated with highly elastic vapor, we have tremendous explosions of thunder and lightning, with rapid precipitations of rain and hail.

* * * * * * *

"If it can be shown that transparent elastic vapor is the vehicle of atmospheric electricity, and that it is rapidly condensed during discharges of lightning, it will neces-

sarily follow that the caloric of such vapor is given out in the concentrated form of electricity during a thunder-storm.

* * * * * * *

"The fabled Proteus of old is but a feeble representation of the rapid changes through which caloric passes—now silently bearing the waters of the ocean aloft in the atmosphere in a state of transparent ethereal vapor; now darting vivid corruscations from its aerial palaces on high; leaping upon the mountains and cleaving the rocks asunder; resounding through the heavens with its great music, and sprinkling the earth with genial showers of fruitful rain. Though constantly changing, it is never destroyed, but is always the same powerful agent by which Infinite Wisdom directs and governs the universe. Who can refrain from sentiments of profound admiration of its God-like energy, and the wonderful manner in which it produces an endless succession of the most diversified effects?

"There is not a more striking evidence of beneficent design in the whole mechanism of creation than the rapid evolution of heat, from atmospheric vapor, in the concentrated form of lightning, during hot and sultry weather. Were it evolved gradually, as during winter, the number of rainy days would be so far increased as greatly to interfere with the operations of agriculture. On the other hand, being given out in the diffused form of sensible heat during the formation of clouds, rain, and snow in the higher latitudes, it moderates the excessive cold, which would otherwise prevail during winter."

It appears conclusive from the foregoing remarks of the learned writer, that the mechanical arrangement I have described, for cooling and drying the air when it is very hot and sultry, is only wanting in magnitude to produce a regular thunder-storm in the air-duct. The electricity will probabably be evolved in precisely the same manner that it is in the heavens when very cold and very warm currents of air are brought suddenly together, but it will be on so comparatively small a scale that the observable phenomena of the thunder-storm will not be apparent.

It is reasonable, however, to expect that the same pleasant effect would be had upon the air that a thunder-storm has, viz: to give it a peculiar freshness, as if it had been washed clean, and as if it possessed renewed vital powers, giving every one elastic spirits and additional life and strength.

Since the discovery of ozone by the late celebrated German chemist, Schoenbein, it is generally supposed that the electric fluid developed during thunder-storms gave that condition in considerable degree to the oxygen of the air, and that its delightful freshness and invigorating character, as experienced after a thunder-storm, were due to this cause, ozone being a condition of oxygen, which causes it to enter into chemical union with other substances with greatly increased avidity. When, therefore, we breathe air, of which the oxygen is in this condition, or which is impregnated with this principle, it unites with an increased readiness with the carbon and hydrogen which pass into it out of the blood, through the membranes of the lungs.

There is also good reason to believe that cooling the air by first compressing it, as I have recommended, will have the effect of developing ozone. Dr. Wetherill states in his report, to which I have several times alluded, page 91, that—

"M. Saint Pierre (Comptes-Rendus, lviii, 420, 1864) discovered a remarkable production of ozone by the action of certain kinds of ventilating apparatus. He found that test-paper, placed in the tuyere of a blast furnace, gave evidence of ozone in a much stronger manner than when in the external air; and to show that the velocity of the current bringing greater quantities of air to the paper was not the cause of the reaction, he placed, at the same time, similar papers upon the governor of a steam-engine in a saw-mill. From these and other experiments, he concludes that the reaction arises from compressing the air."

Whether this desirable condition of the air would be imparted to it by the mechanism described, or not, there can be no doubt but the temperature and moisture of the external air could be modified, by the system I have recommended, from its most unpleasant condition in any season of the year to that which is most delightful, and without imparting to it any impurities or unpleasant odors.

To supply the necessary quantity of steam to the blowing and cooling engines I would remove the present boilers and increase the available space in the boiler-room by removing the groined ceiling and the accompanying ribs from the side walls, and employ iron beams to support the pavement roof, all as shown in plate V of the illustrations. At present two chimneys, situated in the walls of the connecting corridor, are used to carry off the products of combustion from the boiler furnaces. There is a third one, not used at present, of which I would avail myself, and this would give a sufficient chimney area.

The aggregate potential dimensions of the four boilers would be as follows:

	Square feet.
Grate surface	300
Heating surface	13,744
Calorimeter through tubes	73
Calorimeter through chimneys	44

Height of chimneys above grate, 100 feet.

The maximum demand for boiler power will be when the cooling engine is in operation to its full power, requiring at such times a force of 1,320 horse-power. The blowing engines would then be running at their slowest rate, and would not consume more than 50 horse-power, making a total demand upon the boilers of 1,370 horse-power. It will be observed that the boilers would have 10 square feet of heating surface to each horse-power, a usual proportion.

COST.

I have carefully ascertained how much it will cost to carry out the foregoing programme, and although it amounts to a larger sum in the aggregate than I find contemplated in any of the various reports which have been made on this subject, it is very much less than was expended by the British House of Commons upon improving the ventilation of their hall, though it has the addition of the cooling and drying apparatus, the cost of which is a material addition to the expense; and, moreover, draws its air from an unobjectionable locality through a beautiful wire-work dome, which removes the dust, and then through a long underground tunnel; while the air for the House of Commons is drawn through the side windows of the basement story, which on one side overlook the court-yard where the carriages come for the members. The smell, as of an unclean stable, became so offensive that orders had to to be issued that horses should not stand there when waiting. On the other side the windows overlook the Thames, and orders had to be issued in this direction against the passage near the building of barges filled with offal. I do not know the exact amount they have expended, but the following extract from the evidence of the Hon. E. P. Bouverie, M. P., a member of the House committee on ventilation, before a committee of the House of Lords, May 12, 1854, will give an idea of it:

"Question 762. Do you not think that Mr. Gurney's improvement in the ventilation of the house is mainly attributable to the windows being open?

"Answer. I have heard it said that the result of our spending £200,000 in the ventilation of the House of Commons has been to prove that the best way of ventilating the room is by opening the windows. We sit in the house a good many hours after the windows are shut; for instance, we did so last night, and the air, I think, remains very fresh and good."

Here is an expenditure of $1,000,000 in gold, with labor and materials so much cheaper than in this country that it would require $2,000,000 of our present currency to effect the same work here now, and even then they had not arrived at a fully satisfactory con dition of their hall, as they made several changes subsequent to the above date.

The whole cost of the Capitol building up to the present time is about $12,000,000, and it is correspondingly grand in its conception and beautiful in its details. The materials are of the highest order ever employed in building, and they are brought together with an exquisite taste and skill, which is probably unsurpassed in any edifice in the world.

The new wings are so arranged that mechanical ventilation is the only proper method, and that was adopted and is now in use. But the mechanism is utterly inadequate in its dimensions and power, is arranged upon erroneous principles, and is faulty in every detail of its design. It propels a feeble current of air up through the floor of the hall near the western end, which current continues directly upward and out through the ceiling without having done much to ventilate anybody. In winter it is heated by rusty iron steam-pipes, without being moistened, and in summer the little ventilation there is may be said to depend upon the open doors.

Such a system in such an edifice is simply disgraceful. How much honor is reflected upon the nation by imposing colonnaded façades of purest marble; by grand corridors with tesselated floors, bronze doors and frescoed walls; by the hall's great dimensions, or its gorgeous gildings and other ornamentations, if the whole is kept filled with a mephitic atmosphere by a defective and deficient ventilating mechanism?

The conception of the ventilation of such an edifice should be as complete and superior in its character as a scientific and mechanical work, as the building itself is as an architectural one.

The mechanism should be indebted for the principles which govern its arrangement and operation to a correct application of known physical laws. It should be scientifically proportioned throughout all its details, that it might correspond with the building and with the work it had to perform. Each part should represent the highest skill in the arts to which it pertains in its design, its materials, and its workmanship and finish.

In making the necessary examination of the building, with the view of preparing this report, I was greatly aided by the courtesy and assistance of the Architect of the Capitol Extension, Mr. Edward Clark, who gave me free access to all the plans and records of his office, and supplied me with much valuable information I would otherwise have been unable to obtain without great additional labor.

I am also indebted to the engineer in charge of the ventilation, Mr. J. Thomas Mil-

ler, and his assistant, Mr. H. F. Hayden, for assistance and information, rendered with the greatest cordiality.

I am, very respectfully, your obedient servant,

ALBAN C. STIMERS.

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, House of Representatives.

Estimate of A. C. Stimers.

OFFICE OF ALBAN C. STIMERS, NAVAL ENGINEER,
No. 45 *William Street, New York, December* 15, 1868.

SIR: In accordance with the expressed desire of the committee in July last, that I should ascertain the net cost of executing the work of introducing a proper system of ventilation for the House wing of the United States Capitol, and report the same to you at this time, I beg leave very respectfully to submit the following detailed statement as the result of my investigations:

Excavating the inlet tunnel; bricking and cementing ditto; coping ditto with granite, and furnishing with marble curb, 28 feet internal diameter and 4½ feet high at inlet, and paving around the curb; block-tin wire screen dome at inlet, 25 feet diameter at base by 22 feet high, of ¼-inch wire and 1¼-inch mesh, with revolving fountain on top; and water pipe and sewer.	$103, 103
Eight patent blowers, each having a capacity of driving 200,000 cubic feet of air per minute, including shafting, hangers, pulleys, &c., erected in place, complete	11, 194
Pair of surface-condensing engines of 750 horse-power, with wood-gear fly-wheel; patent variable cut-off and steam-jacketed cylinders for driving blowers; all erected in place, complete	46, 102
Removing masonry from the engine-room and tempering air-ducts, and replacing it with iron girders and columns; providing cut granite foundations for engines; opening and properly dividing the vertical air-ducts back of the grand stairways, and building inclosing walls between vertical air-ducts and main chamber over hall ceiling; and putting in stairs from basement to engine-room in cellar	70, 994
Removing ceiling and ribs from boiler-room; removing present boilers; laying foundations for new boilers; providing new pavement roof with iron girder beams; enlarging smoke conduit from boilers to chimneys, and opening and topping out additional chimney	40, 133
Four boilers and their appurtenances, having, in the aggregate, 300 square feet of grate surface, 13,744 square feet of heating surface, 73 square feet calorimeter through tubes, and capable of generating steam for 1,370 horse-power, and of sustaining a working pressure of 40 pounds per square inch, all set in place complete, and fitted with copper steam-pipes to engines	63, 416
Providing an extra ceiling of plate glass and iron of double thickness, extending over the entire hall and the grand stairways, rearranging the gas fixtures over new ceiling, perforating the ceiling for the passage of the air into the hall, and supplying wire screen deflectors to distribute the air equally over all parts of the ceiling	66, 335
Wire gauze fitted to backs of seats in galleries for passage of foul air through floor of galleries; perforated plates fitted to inside of front of galleries for passage of foul air; perforated plates fitted to cornice of front of galleries, for passage of foul air, and to prevent the exhalations from persons leaning over it from passing down to members on the floor; and additional registers in the hall floor, so that there shall be at least one at each desk	9, 508
Removing bricks enough from between air-ducts beneath the hall floor to convert it essentially into one chamber, cutting an air-duct from beneath the hall floor to the exhausting blowers at the east end of the wing	12, 726
Heating apparatus, having 44,582 square feet of block-tin tubular surface, arranged in eight congeries with steam and water pipes and valves complete, erected in place	123, 018
Providing eight gas fireplaces, with marble mantels complete, in the cloak-rooms; new registers and fitting up committee and cloak rooms	8, 709
Moistening apparatus, made entirely of block-tin pipe and equivalent to 40,000 square feet of fan surface	5, 792
Pair of surface-condensing engines of 1,320 horse-power, having cylinders of 45 inches diameter by 6 feet stroke, and connected with these a pair of air-compressing pumps of 65 inches diameter by 6 feet stroke, and a tubular compressed-air cooler, having 9,000 square feet of brass tube surface; all erected in place, complete, for cooling the air in hot weather	94, 552

Drying apparatus, having 5,570 square feet of block-tin tubular surface, with regulating valves complete, for removing the moisture from the air when it is too damp, or when it is made so by having cooled it	$30,754
Indicating air-pipes, hygroscopes, hot-well thermometers, steam cylinder indicator, engine-counters, and clock for engine-room	2,317
Total	688,653

I am prepared to enter into contract to execute the foregoing work in full accordance with the letter and spirit of my report to you of this date on the subject of ventilating the House wing, and furnish satisfactory sureties for the above-named sum of $688,653, provided that if, after it is completed and tried, the House shall pass a resolution of satisfaction with my work, I shall receive a further sum of 12½ per cent. of the above amount as a profit, the sum herein named being the net cost to me of doing the work.

I am, very respectfully, your obedient servant,

ALBAN C. STIMERS.

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, House of Representatives.

Reply of Edward Clark, Architect of the Capitol Extension.

ARCHITECT'S OFFICE, U. S. CAPITOL EXTENSION,
Washington, D. C., January 11, 1869.

SIR: I have the honor to acknowledge yours of the 8th instant, transmitting plans, and report of Mr. A. C. Stimers, on the subject of ventilating the hall of Representatives, and requesting my opinion thereon, in regard to whether the execution of these plans would interfere with the structure, &c.

In reply, I have to say that after examining the plans, I do not consider that their execution will affect the stability of the structure as far as the walls and foundation are concerned, but at the same time I do not feel myself competent to give a reliable opinion as to whether the iron rafters are capable of sustaining the increased weight which would be imposed on them.

The report and plans are herewith returned.

I am, very respectfully, your obedient servant,

EDWARD CLARK, *Architect.*

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, U. S. House of Representatives.

Reply of A. C. Stimers.

OFFICE OF ALBAN C. STIMERS, NAVAL ENGINEER,
No. 45 *William Street, New York, January* 15, 1869.

SIR: As the Architect of the Capitol does not pronounce upon the question of whether the rafters over the hall have sufficient surplus strength to carry with safety the additional ceiling I propose to place above the present one to form an air conduit, I present you with the results of my own calculations as follows:

Weight which may be placed with safety upon each rafter		67,500 lbs.
Weight of each rafter	12,000	
Weight of roof over each rafter	8,000	
Weight of ceiling suspended to each rafter	15,000	
Weight of proposed ceiling suspended to each rafter	9,000	
Total weight upon each rafter, including new ceiling		44,000 lbs.
Surplus strength after new ceiling is built		23,500 lbs.

I am, very respectfully,

ALBAN C. STIMERS.

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, House of Representatives.

Reply of Horatio Allen.

NEW YORK, *January* 26, 1869.

SIR: I have received your letter of 20th instant, accompanied by Mr. Stimers's report on ventilation, &c. My opinion is asked, "Whether, if the plans of Mr. Stimers be carried through, the results promised in the report will probably be obtained."

The report is very full and very elaborate, and I regret that the shortness of the time allowed for its consideration, and engagements which require my attention, prevent such an examination as to the results of the cooling instrumentalities as will enable me to express an opinion as to that part of the proposed plans.

Mr. Stimers has presented very fully the various means to be used to effect a complete and thorough ventilation.

The provision for obtaining the air from an unobjectionable source and depriving it of dust; the method of forcing the air into and out of the halls, and securing a proper distribution; the mode and means of warming the air and effecting the proper degree of moisture—all appear to me excellent and well calculated to produce the result desired.

The method proposed for cooling the air by the introduction of compressed air, which expands on entering, has only recently been made use of, and I have not the time to possess myself of the practical information on which to base an opinion.

Yours, respectfully,

HORATIO ALLEN.

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, House of Representatives.

OFFICE OF ALBAN C. STIMERS, NAVAL ENGINEER,
No. 45 William Street, New York, February 5, 1869.

SIR: As Mr. Allen does not express an opinion as to whether the mechanism I propose for cooling the air in hot weather will produce the results promised in my report, I beg leave to call your attention to the following extracts from standard professional works, by which you will perceive that Mr. Allen cannot be understood as denying in any manner that a powerful cooling influence will be produced by my engine of 1,320 horse-power, but only that he is not prepared at present to say that I will get, on a large, practical scale, the exact amount promised.

In John Bourne's "Recent Improvements in the Steam-Engine," 1865, pp. 237, 238, there occurs the following:

"ICE-MAKING MACHINES.

"One of the most remarkable applications of the steam-engine is to the manufacture of ice, which is accomplished by forcing the heat out of air by mechanical compression, and then by again allowing the compressed air to expand. Such demand is thus created for the restoration of the heat before forced out as to produce a great reduction in the temperature of surrounding objects. On the occasion of my first visit to India, in 1847, the inconveniences caused by the heat drew my attention to the subject of artificial refrigeration, which I proposed to accomplish by compressing air until its temperature became so high that its surplus heat would be readily extracted by the application of cold water; and then by allowing this air subsequently to expand under such circumstances as to generate power, a very low temperature it was plain would be produced, which might be regulated to suit the requirements of a practical system of refrigeration. Subsequently the same idea was propounded by various other parties; and an ice-making machine has been constructed, in which refrigeration is produced by power aided by the agency of ether. But in Kirk's machine for producing cold the ether is discarded and air alone is used, which air is passed through a regenerator, as in Sterling's air-engine. This machine is now in successful use in Young's Paraffine Works, in Scotland."

[From Mechanics' Magazine, (London,) 1857, vol. 66, page 125.]

"DESCRIPTION OF ENGINE.—ICE FORMED IN CYLINDER BY EXHAUST—DISCUSSION.

"Professor Rankine remarked that the same principle (*i. e.*, compression of air) had been applied by Professor Piazzi Smyth to the cooling of air for ventilation; compressed air was passed through tubes surrounded by water, so as to abstract the heat produced by compression, and, by being allowed to expand again, was cooled.

"Mr. Randolph calculated that the temperature due to compression of air to 30 pounds to the square inch would melt tin.*

* Tin melts at 442° Fahrenheit.

"Professor Rankine stated Dr. Gerrie, of Florida, made the first machine for making ice in this manner. Page 126—Mr. Fothergill saw an ice machine in London about 1843. (For Dr. Gerrie's account see Appleton's Magazine, 1851, page 375.)"

In the inaugural address of Mr. Elliot, president of the North of England Institute of Mining Engineers, (*vide* Van Nostrand's Engineering Magazine for January, 1869, p. 23,) he said:

"With regard to the duration of the coal supply in Great Britain I have no hesitation in expressing my opinion that it depends in a great degree upon the scientific improvements we are able to make in our mode of ventilating the workings. It is probable that the ordinary means of ventilation, whether by furnace or fan, may be aided by a change in the force or agency employed for the purpose of haulage and other underground work. As an instance of my meaning I may mention that the apparatus which I have introduced in South Wales, and which, by means of compressed air used as a motive power instead of steam, draws trams and pumps water with complete success, is found to generate ice in an atmosphere which is naturally hot and oppressive. The mechanical usefulness of these new air-engines seems capable of indefinite extension; while, as their cooling properties form a collateral advantage arising out of their use, it is at least possible that they may prove valuable auxiliaries to the more regular means of ventilation in extending the security and promoting the healthfulness of our mines. The difficulties of ventilation once surmounted, the extent of coal at our disposal is incalculably increased."

An ice-making machine was recently made in the Novelty Iron Works in this city—of which Mr. Allen is president—with which ice was made by cooling compressed air, and then permitting it to expand. The mechanic who had charge of its construction informs me that he had a small stop-cock on the top of the compressed air-chest, opening upward, and that when he opened this the moisture in the escaping air was immediately frozen, and there appeared a fountain of hail of exquisite beauty.

Mr. George H. Reynolds, superintendent of the De Lamater Iron Works of this city, informed me that he recently erected some air pumps for compressing the air used at a Bessemer steel works, and employed rubber valves. He says that with a pressure of 20 pounds per square inch the valves gave no trouble, but that with 25 pounds the heat was so great as to melt them. Now such rubber melts at about 300° Fahrenheit, and according to the formula I have employed, 20 pounds per square inch gives 283° Fahrenheit, when the air before compression is 95°.

This is pretty strong evidence that the formula cannot be much out of the way when applied to large practical operations.

You will observe that Mr. Allen indorses thoroughly every part of my report, which covers all the attempts of those who have preceded me in this branch of engineering, my proposal to cool the air of ventilation by steam-power being entirely new in this country.

As Mr. Smith emphatically indorses every part of the report, including the cooling, I will only remark that I have yet to learn of his having ever indorsed anything which afterward failed to give entire satisfaction.

I could give you many more extracts from various professional works regarding the efficiency of my proposed method of cooling the air, but as they are of a similar character to those given herein, they would not add to the force of this letter.

I am, very respectfully, your obedient servant,

ALBAN C. STIMERS.

Hon. STEPHEN TABER,
Chairman Committee on Ventilation, House of Representatives.

Proposition to warm in cold weather, cool in hot weather, and ventilate at all times, the Capitol extension, by Alban C. Stimers, naval engineer.

45 WILLIAM STREET, NEW YORK,
January 27, 1870.

SIR: Since the date of my report to the select committee of the House of Representatives (H. R. Rep. No. 19, third session Fortieth Congress, December 15, 1868) I have been studying how I could accomplish the perfect ventilation there promised, and reduce the cost.

The suggestion made to me by an honorable member of your committee (Mr. Jenckes) that the machinery employed should not be placed under the building itself, as is now done and as I had then proposed to do, but to erect a special building for it in the western park, and communicate with both wings by air-ducts only, thus ventilating the whole with one apparatus, was in itself a long step in the desired direction of economy, as in placing the machinery under the building I was compelled to introduce the air through an inlet tunnel of 15 feet diameter and 300 feet in length, while by the plan now proposed all air-ducts may be excavated from the surface, which costs much less

than tunneling. This suggestion also saves the great expense of cutting through massive granite walls in the foundations, and preserving their strength by the use of iron columns and beams. In addition to the advantages of this change on the score of economy, it removes the feeling of objection which existed to having powerful steam machinery in operation immediately beneath the building.

In the report to which I have referred it is explained that a velocity of 5 feet per minute would give a heathful ventilation and enable the mechanism employed to control the current: and the dimensions of the heating, cooling, drying, and moistening apparatus were determined upon the basis of supplying that quantity when the weather was extremely cold or hot, but blowers and blowing engines were to be employed of sufficient power to produce a velocity of 50 feet per minute in the hall, at times when no expenditure was required to change the condition of the air. I find, however, that a constant current of pure air past the person, having a velocity of 10 feet per minute, will give, with downward ventilation, all the sensation of freshness which could be desired. I therefore now propose to limit the power of the blowers and blowing engines to the magnitude necessary to furnish that velocity. For the two halls, the various committee and cloak-rooms, and the corridors of the two wings, this will require 280,000 cubic feet, or say ten tons weight of air per minute. To drive this with four blowers, through four separate ducts, into each end of each wing, and distribute it in the manner described, and to withdraw it with four exhaust blowers through four other separate ducts, and then drive it through a long underground duct to the chimney situated entirely without the grounds, each duct having the cross area hereinafter specified, will require engines of 250 horse-power, in lieu of those of 750 horse-power provided for in my proposition to ventilate the House wing only.

In my former proposition I designed cooling engines of sufficient power to reduce the temperature of the halls 20°, when not only the temperature but the humidity should be at its maximum, the power devoted to drying the air being equivalent to a cooling force of 24° more.

During the past summer I made some very careful observations with the view of determining how much the air may be cooled in hot weather in summer and continue to add to the comfort of the person with each degree of depression shown by the thermometer. The results were such that I became well satisfied I had provided a greater power for that purpose than could be advantageously employed.

The temperature of 75° Fahrenheit is a very pleasant one with summer clothing, but to go suddenly from a temperature of 95° to one of 75° gives an unpleasant sensation of cold, the reverse of comfortable or healthful. To reduce, however, from 95° to 85°, from 90° to 82°, from 85° to 80°, from 80° to 76°, &c., adds charmingly to the comfort, without any sensation of chilliness. This can be accomplished in both wings with cooling engines of 1,000 horse-power.

I propose, also, a further reduction of the cost by leaving out the block-tin wire screen at the entrance of the inlet tunnel, which, with the coping and curb around it, cost $15,000 for the House wing only, and would now introduce the air through the top of the ventilating house; and as it will have no chimneys, and its ventilation will be downward into the boiler furnaces, the purity of the air cannot be impaired as it enters.

Having explained the foregoing as changes from my proposition to the Fortieth Congress, I will proceed to explain my views of what will constitute a good ventilation of the two wings, including the legislative halls and their galleries.

The term *ventilation*, when applied to a building of this importance, should signify *the production and maintenance within doors of pure air, properly tempered with heat and moisture, regardless of the existing state of the weather.*

Thus, to maintain the air pure in any inclosed space occupied by persons, it must be constantly renewed; when the weather is cold the air of renewal must be warmed; when it is hot it must be cooled; when it is too dry it must be moistened; and when it is too moist it must be dried. Further: when air is warmed simply its relative humidity is lessened; and when it is cooled this is increased, so that, generally, when air is warmed it must be moistened, and when it is cooled it must be dried. Properly, however, the degree of moisture in the space ventilated should be as carefully observed as that of its temperature, and that which is most pleasant and healthful should be uniformly maintained, regardless of the condition of the outer air, or of the modifications which may have been made in its temperature.

A consideration of the subject is therefore properly divisible into the following heads:

1. The quantity of air necessary, and how it should be introduced.
2. Warming and moistening the air in cold weather.
3. Cooling and drying the air in hot weather.

The subject of regulating the degree of moisture in the air when it is neither warmed nor cooled is naturally involved in the above.

I. THE QUANTITY OF AIR NECESSARY, AND HOW IT SHOULD BE INTRODUCED.

In treating of the quantity of air required for ventilation, writers generally refer to

the number of cubic feet per minute required for each person in the apartment. This method is, however, defective, in that it does not take into consideration the vacant spaces where the air comes and goes without having come in contact with persons, except as they are to be filled with the somewhat vitiated air with which writers generally appear contented to have pervade occupied apartments.

I consider, however, that any system of ventilation is defective which does not furnish a constant supply of perfectly pure air to the nostrils of every person in an apartment, and to secure this there must be a steady current past the person, having a velocity too low to be perceptible to the senses, but sufficient to furnish a fresh supply to each inhalation. *It is the person, and not the apartment, that requires ventilation.*

Every person is at all times surrounded by an envelope of vitiated air, and the thickness of this envelope is dependent upon the direction and velocity of the air past the person. Thus, the average man is 5 feet 8 inches high and 1 foot thick from front to back. If, therefore, the direction of the current of air past the person is vertical, it will require to have $5\frac{2}{3}$ times the velocity that would be necessary if the direction was horizontal, to maintain the same thickness, or rather thinness, of the vitiated envelope.

Dr. Wetherill, in his interesting report on the ventilation of the Capitol extension, page 66, says:

"Hood (Warming and Ventilation, p. 261) estimates the air required for ventilation by the amount needed to take up the moisture from the skin and lungs. The air required for respiration (*i. e.*, oxidation) is very much less than that needed to hold in solution the vapor of the skin and lungs, which evolve 12 grains of water per minute. If the temperature of a room be at 60°, with a dew-point of 45°, a cubic foot of air will absorb $2\frac{1}{4}$ grains of vapor; or, in other words, the perspiration from the body will saturate $5\frac{1}{3}$ cubic feet of air per minute. If, however, we take the dew-point lower, say not to exceed 20° or 24°, then $3\frac{3}{4}$ cubic feet of air per minute will be required to carry off the insensible perspiration, while for the pulmonary supply one-fourth cubic foot will be needed, making a total of 4 cubic feet. In summer, as the dew-point is higher, more air will be needed, viz. 5 cubic feet per minute for summer ventilation."

In a foot-note to the above it is stated that Seguin gives the exhalation of water from the lungs, 7 grains; from the skin, 11 grains; total, 18 grains, per minute.

This is undoubtedly the correct method of ascertaining the number of cubic feet of air vitiated by each person per minute, and, as will appear further on in this report, the dew-point should be maintained uniformly at 52°; we can make the calculation of quantity exact for this case.

A cubic foot of air at a temperature of 65°, with the dew-point at 52°, will absorb $2\frac{1}{2}$ grains of vapor; and if we take the mean of the two authorities above cited regarding the quantity exhaled by each person, we will have 15 grains per minute; and, to absorb this under the above conditions will require 6 cubic feet of air. Add to this the one-fourth cubic foot required for breathing, and we have $6\frac{1}{4}$ cubic feet as the total amount vitiated per minute.

The surface of an average man is about 18 square feet. If, therefore, we imagine such a man walking in the pure open air at the rate of two miles an hour on a perfectly calm day, the air will be flowing past him at the rate of 176 feet per minute; and, as he is one foot deep from front to back, the average thickness of the envelope of vitiated air which surrounds him may be found as follows:

Let a = The quantity of air vitiated per minute in cubic feet .... = $6\frac{1}{4}$
b = The surface of the person in square feet .... = 18
c = The extent of the person in the direction of the current of air in feet = 1
d = The velocity of the current in feet per minute .... = 176
x = The thickness of envelope in inches.

Then,

$$\frac{12ac}{bd} = x$$

and

$$x = 0.018 \text{ or } \tfrac{1}{54} \text{ of 1 inch.}$$

In supplying air for the ventilation of a hall containing an assemblage of people, however, it is absolutely essential that the direction of the current should be vertical; otherwise that which has been vitiated by one person will be given to another to breathe and perspire into.

If, now, we assume a man standing upright, of the average height of 5 feet 8 inches, and the velocity of the current at 5 feet per minute, we will have for the value of the terms in the above formula—

$$a = 6\tfrac{1}{4}$$
$$b = 18$$
$$c = 5\tfrac{2}{3}$$
$$d = 5$$

Whereupon

$$x = 4.16 \text{ inches.}$$

If this envelope of 4 inches thickness of vitiated air be drawn upward, it is clear that the nose and mouth will be always supplied entirely with vitiated air, no matter how pure it may be one foot away; while if it is drawn downward, those organs will always be supplied with perfectly pure air. This consideration alone is quite sufficient to determine us in favor of the downward direction. There are, however, some other advantages in the downward over the upward direction, which it may be well to state.

The temperature of the human body rarely varies 2° either way from 98°, a sudden variation of 5° or 6° being said to be fatal. If, therefore, the air is supplied at a temperature of 65°, it will be 32° cooler than the body; with the downward current, the head will be in this cool air, while the feet will be inclosed in an atmosphere nearly if not quite as warm as the blood within them. And to "*keep the head cool and the feet warm*" is one of the fundamental rules of hygiene as well as of comfort.

Again, with upward ventilation the entire halls are filled with vitiated air, the vitiation having taken place near the point of admission; while with downward ventilation the vitiation takes place near the point of exit, and the whole upper part is full of pure air.

The height from floor to ceiling of the halls is 36 feet; if, therefore, the air is admitted through apertures well distributed in the ceilings, it has 30 feet to move before it comes in contact with the heads of persons on the floors. During this movement all eddying currents, induced by the increased velocity with which it is necessary that it shall pass through the apertures have become quiet, and the whole mass descends with a uniformity impossible to obtain in the vicinity of the persons ventilated with upward ventilation; and *one of the most important considerations to be kept in view in ventilating an apartment is to avoid perceptible draughts.*

Mr. Goldsworth Gurney, in his examination before a committee of the House of Lords of the British Parliament, March 24, 1854, said in reply to the question:

"In those courts which you have ventilated, you have found your system answer?"

"Yes, we have found the down current always more agreeable. The up current is sometimes used, but it is not so pleasing, and not so effectual."

The hall of the Massachusetts house of representatives has recently been provided with new ventilating arrangements, and the downward system has been adopted.

One objection brought against the downward system is that it is against nature to force air downward. Although this opinion is entertained by an extremely large number of otherwise well-informed persons, every engineer of ordinary attainments knows perfectly well that it is as easy to force air in one direction as another. Another objection is, that as the air is warmed at the same time that it is vitiated, that which is thus vitiated and warmed has a tendency to rise, whatever may be the direction of the general mass surrounding it. This is true, but this tendency is so feeble that its opposition to a current of 5 feet per minute would not be perceptible.

It has been shown that with a vertical current of 5 feet per minute, the mean thickness of the envelope of vitiated air surrounding a man of the average size, when standing, is four inches. This is more than two hundred times as thick as when he is walking at the rate of two miles an hour in a perfect calm. As, however, the air is to be brought from such a direction that the mouth and nose are always supplied with air of absolute purity, and the velocity is sufficient to insure the control of its direction by the mechanical means employed, I have assumed it for the *minimum* velocity to be given.

When the weather is fine, or, in other words, when the outer air from which the supply is derived, is in the desired condition as regards temperature and moisture, and no expenditure is required upon its condition, then a *maximum* amount may be given, the *minimum* being employed when its condition as regards temperature and moisture has to be changed to the greatest extent. The only limit to the amount of air it will be advantageous to supply is that fixed by the rule, that the currents past the person must not be sufficiently rapid to become sensible. Some persons are sensible to currents of much lower velocity than is required to render others conscious of them. Most people can feel a current having a velocity of 150 feet per minute; very few can perceive one of 90 feet per minute.

The most delicate person would, therefore, be unconscious of a current of 50 feet per minute, but as 10 feet per minute will give a beautiful fresh ventilation, I propose, for reasons of economy, to limit myself to furnishing that for a maximum velocity. The average thickness of the vitiated envelope will then be two inches, or one hundred times thicker than when walking out doors in a calm. With downward ventilation, however, the nostrils are in the pure air equally as when walking, the vitiated air enveloping the lower part of the person only, leaving us unconscious of its presence.

The Senate chamber is 115 feet 6 inches long by 81 feet wide. The hall of the House is 139 feet 4 inches long by 93 wide. The downward current within them would therefore have a combined transverse area of 22,284 square feet. A velocity of 5 feet per minute would then require a supply of 111,420 cubic feet, and one of 10 feet per minute a volume of 222,840 cubic feet per minute, to supply the legislative halls only. The

committee and clerk's rooms and the corridors need a supply that would carry these numbers to 140,000 and 280,000 respectively.

The provisions for heating, cooling, moistening, and drying the air should, therefore, correspond with the lesser, while those for propelling it into and out of the building should be adequate to control the greater of the above quantities.

The first method adopted by engineers and architects to give movements to air for the ventilation of mines and buildings was to heat an up-flowing column, thus lessening its specific gravity and causing it to rise with corresponding force. That system is still employed in the British houses of Parliament, where in each of its many towers a charcoal fire is kept burning, and thus a force obtained to propel the air through the building.

During the past year screw-propeller fans, driven by steam-engines, have been introduced into several of these towers to insure a proper draught in unfavorable weather.

It has been practically demonstrated, however, that one pound of coal burned in the furnace of a steam boiler, which furnishes steam to drive a fan blower, will generate as much force, and consequently is capable of producing as strong a current of air as 38 pounds expended in heating a column of air to act by its diminished gravity.

English mining engineers commenced about ten years ago to apply fan blowers to the ventilation of mines. The French had previously adopted the same practice. In addition to the economy of this method, the complete control which the attendant is enabled to maintain over the quantity of air supplied at all times is found to be of great advantage.

Since mankind have lived in houses, windows have been placed in the sides, which it has been the habit to open when the weather was favorable for the purpose of ventilating the apartments within. This practice has been so general, that surrounding the legislative halls of Congress with corridors and committee-rooms, as has been done with the new wings of the Capitol, is regarded with great disfavor; and many people are decidedly of the opinion that they never can be satisfactorily ventilated until the halls themselves are brought out to the sides of the building, and have windows opening directly into them. It is regarded as a fault in the architecture that the only practicable ventilation must be such as would supply air to any pent up place.

For any inclosed space, however, where large numbers of people collect and remain during several hours every day, windows in the sides, which communicate directly with the weather, would manifestly be of no avail when kept closed, as they must necessarily be except in good weather; and even then they are not effective unless the wind is blowing. A remarkable proof of this occurred in Calcutta more than a hundred years ago.

On the 19th day of June, 1756, the native Indian forces attacked and captured Calcutta from the English. At night they thrust one hundred and forty-six English prisoners into what was known as the "Black-hole prison." This was a room on a level with the ground, eighteen feet square, with two open windows on one side, barred, of course, to prevent escape, but free to admit air and light.

These prisoners had not been in the place five minutes before they discovered that they were in danger of suffocation, and, indeed, the weakest soon began to become insensible. Those near the windows entreated the guard on the outside to have them put somewhere else, and a message was sent to the commander of the Indian forces to inform him of the state of affairs; but he was asleep, and Eastern etiquette would not permit of his being awakened, and as he slept until morning no relief was afforded during the whole night. Meantime one hundred and twenty-three of the prisoners died for want of fresh air, only twenty-three living to walk out when the door was opened. These were nearly dead, and did not recover their health until after having passed through a severe attack of boils, which broke out all over the entire person. In this case the windows were ineffective as ventilators, simply because the night happened to be calm.

Even when the weather is good, the temperature of the air delightful, and the wind blowing with the most desirable force, an open window in the side of a great hall, filled with an assemblage of people, would furnish air to those farthest from the windows filled with emanations of all the persons it had passed on its way.

To propel the air into the building I would therefore employ four fan blowers, having in the aggregate a capacity of 280,000 cubic feet per minute. These would be situated on the ground floor in the ventilating-house already mentioned, and from each there would be a separate air duct, one leading to the upper part of each wing into the chambers above the ceilings. Those in the south wing would pass up back of the grand stairways, and would each have a cross area of 20 square feet. Those in the north wing would pass up in the southwest and southeast corners, and would each have a cross area of 15 square feet.

Above the ceilings I would provide additional ceilings of plate glass and iron of double thickness, that they might be non-conductors of heat, and above these I would fix the gas burners, adding about fifty per cent. to the present number. These extra ceilings form air ducts of such character that the air may be thoroughly distributed over the

ceilings before passing down into the halls. As the glass in the ceilings would be of the best quality of clear plate it would be no perceptible obstruction to the light, even if the gas-burners were not increased in number; while, as there would be six inches depth of confined air between the two thicknesses, neither the heat of the summer sun nor that of the gas-lights would raise the temperature of the inflowing air; and in winter they would equally protect the warmth which had been previously given to it. Openings through the present ceilings would be provided such that their present ornamental appearance would not be changed, and an equal area of opening would be obtained in each of the many squares into which they are divided.

To insure the continuance of the air thus admitted through the ceilings in a direct vertical line down to the floors and to the galleries, frequent openings throughout their extent, which should communicate with the air chambers beneath the floors, would be made, especial means being provided to prevent the foul air from the galleries from flowing down upon the members on the floors; and from these sub-chambers I would withdraw the air by means of four fan-blowers, of equal dimensions with those employed to drive it in. These foul-air blowers would also be situated in the ventilating house, and each would have its separate duct leading from each end of each wing.

These air-ducts, four from each wing to the ventilating house, would be made of brick, and arranged in congeries, the top of each congeries being situated six feet beneath the surface of the ground, so as not to interfere with any desired situation of trees.

The foul-air blowers deliver the air they have withdrawn from the building into an underground conduit common to them all, into the center of which will also be delivered the escaping gasses from the steam-boilers upon which the air from the blowers will act in the manner of an ejector, securing at all times an efficient draught through the boilers. This conduit will extend to the base of a chimney situated without the grounds, so that the foul air and smoke will be delivered at a distance from the Capitol and from the supply of pure air. All these blowers would be driven by one pair of engines, through the medium of appropriate gearing, shafts, and belts. In every case of gearing there would be wooden teeth working into cut-metal gear, which, it is well known, may be made to run with perfect silence, and is more durable than metal gearing. By running all the blowers from one pair of engines, a uniform relation of the forces employed in different localities is thoroughly secured under all circumstances. It will thus be perceived that the air would be driven in through the ceilings and drawn out through the floors with equal force, and that if the doors are left open into the corridors, either from the floor or from the galleries, there will be no tendency for the air to flow either into or out of the hall. At present the provision for the egress of the air through the ceilings is so much greater than that for forcing it up through the floors that there is a constant flow into the halls from the corridors through every open door, both on the floors and in the galleries. (*vide* the Hon. John Covode's report on the ventilation of the hall of the House of Representatives, made June 20, 1868, p. 2.)

If the forces employed to drive the air in through the ceilings were greatly in excess of those provided for drawing it out through the floors, and the doors were left open, the direction of the current would be changed from the direct vertical line to oblique ones toward the doors, and while those sitting near the walls might get their share of pure air, those in the center of the floors would not.

Again, if the forces for withdrawing the air were greatly in excess of those for supplying it, the air would flow into the halls from the corridors through the open doors, disturbing the direction and equal distribution of the pure air, and interfering with whatever modification there had been made in its condition as to warmth and moisture.

By the plan proposed, however, complete control is maintained over the direction, distribution, and velocity of the entire mass of air which fills the halls.

Messrs. Shedd and Edson, in their report on ventilation to a committee of the Massachusetts house of representatives, dated January 1, 1865, remark in regard to this as follows:

"As regards the manner of applying the power to effect the change of air, it is sometimes applied to the exhaustion of the foul air and sometimes to the supply of the fresh air. Either way is effectual in a degree, but neither alone accomplishes quite all that is to be desired. Forcing the fresh air in abundantly will drive out the air already in the hall at every outlet, and it is essential for security against the intrusion of cold currents through cracks and doorways. But it will drive out mainly at the easiest outlets, and some of the most important may be neglected because of being out of the easiest way for the air to pass. The only sure way to get the air out just where you want it to go out is to apply an exhausting force at the outlets to guide and assist the expelling force. The filling method is called the plenum method, and the exhausting the vacuum method.

"Much has been said about the superiority for working vigor of air in a plenum or

over-pressure condition. There is no doubt of the fact that under a high atmospheric pressure a man has greater power than under a low pressure. But the amount of superior pressure that can be obtained in a common hall is very slight and can hardly have a perceptible effect. A nearly even balance of the filling and exhausting forces, making the in-door barometer about the same as the out-door, but with the filling force enough in excess to keep out all air seeking to enter without leave, is the most economical and satisfactory condition to obtain."

The power of the blowing engines has been determined in the following manner:

The aggregate transverse area of the pure air ducts is 70 square feet, and the total quantity of air supplied is 280,000 cubic feet per minute.

Let v = velocity of air through ducts in feet per second; then

$$v = \frac{280000}{70 \times 60} = 66\tfrac{2}{3}$$

To find the velocity per square foot necessary to produce this velocity

Let v = velocity in feet per second .... $= 66\tfrac{2}{3}$
w = weight of air per cubic foot .... $= 0.075$
g = accelerating force of gravity .... $= 32.$
p = pressure in pounds per square foot—

Then,

$$p = w\frac{v^2}{2g} = 5.2$$

To maintain this pressure at the ends of the long ducts farthest from the blowers, it must be doubled at the blowers, on account of the friction and the obstructions caused by changes of direction, making 10.4 pounds per square foot.

Then 10 per cent. of the power of the engines must be allowed for that necessary to drive the engines, the shafting, and the blowers: leaving 90 per cent. of the power as applicable to the production of the pressure of 10.4 pounds per square foot and velocity of $66\tfrac{2}{3}$ feet per second.

The power required to drive the pure air into the building would then be as follows:

$$HP = \frac{70 \times 66\tfrac{2}{3} \times 60 \times 10.4 \times 100}{33000 \times 90} = 98$$

It requires an equal power to drive the foul air from the ventilating house to the chimney and out of it, and the air thus driven is drawn through long ducts, the friction of which absorbs one half the power. To perform the whole work the above quantity must therefore be increased two and a half times.

The total power required will therefore be as follows:

$$HP = 98 \times 2.5 = 245,$$

or, in round numbers, 250.

PLACE OF OBTAINING THE AIR.

In the report of Senator Buckalew to the Senate, from the Joint Select Committee on Ventilation, made February 20, 1865, he says:

"The air for ventilating the halls is now taken from the level of the terraces between the wings and the old Capitol building on the western side. To these situations much dust and other impurities are carried by the action of the winds, subjected to the influence of eddies, and taken with the air through the ventilating passages into the halls. And in warm weather, the terraces and adjoining walls becoming heated, affect very considerably the temperature of the air obtained. Reference upon this point of the inquiry is made to the testimony of Dr. Antisell, and Mr. Forney, the engineer in charge of the ventilation of the House of Representatives. It is manifest that the air introduced into the halls should be obtained from places not subject to the accumulation of impurities, or to the undue production of heat."

The architect of the Capitol, Mr. Edward Clark, in a report dated November 1, 1866, states:

"Objections have been made to the fresh-air source. The present inlets are near the angles of the wings and connecting corridors, and are liable at all times to admit dust, and oftentimes do admit other impurities thrown from the windows; besides, the air at this place has an increased temperature in summer, obtained from the heated walls and pavement.

"In order to obtain a purer, and in summer a cooler, supply of air, it is proposed to construct an underground duct, opening in the eastern grounds, which opening could be made an ornamental feature by placing a fountain in its center. The jets and overflow would assist in cooling the air and to rid it of any mechanical impurities with which it might be charged. A separate duct and fountain will be required for each wing."

Mr. Charles F. Anderson, an architect and civil engineer, in a report to the Joint

Select Committee on Ventilation, &c., says that the present plan "receives the exterior air under the ground floor from off the surface of the overheated and dusty terraces, furnishing much of the bad air from beneath, carried to its surface by evaporation and side currents of air from the ground; and this air is also tainted with much of the odors caused by the machinery near which it passes." This gentleman proposed the erection of high towers to serve as openings to the inlet ducts.

It has already been explained that I propose to obtain the air at the top of the ventilating house, which will be situated in the center of the western park, where there will be no influences affecting its perfect purity.

II. WARMING AND MOISTENING THE AIR IN COLD WEATHER.

There are three methods in common use for warming the air of ventilation in buildings: First, by passing it over iron surfaces which are heated directly with fire and the products of combustion; second, by passing it over iron pipes filled with steam; and third, by passing it over iron pipes filled with hot water. The first of these methods is considered as so highly objectionable as to be entirely discarded in first-class buildings. When air is brought in contact with highly heated iron surfaces an unpleasant odor is given to it, so that people say that it is burnt, and there is a general belief that it is a very unhealthy air to breathe.

The employment of steam-pipes is regarded as an amelioration of the above difficulty, as their temperature is not so elevated; and hot water is used in preference to steam in order more fully to secure the same end.

In the examination of Mr. Goldsworth Gurney before a committee of the British House of Commons, March 31, 1854, he testified as follows upon this point:

"Question 31. Do you think that the offensive smell may arise in any degree from the use of metal pipes?—Answer. There is sometimes what is called a 'ferruginous odor' produced from iron pipes, but I believe not much in the present case: burnt air is the great source, the decomposition of small particles of animal matter which always float about in the atmosphere. This question has been settled by French philosophers many years ago; it is not from the decomposition of the nitrogen and oxygen, but from the decomposition of these ammoniacal matters which are always found more or less in the atmosphere.

"Question 32. Would you be disposed to recommend any other material than iron for the warming pipes?—Answer. I should prefer zinc; it is clean, a good conductor, and radiates heat well."

My own opinion is that the rusty surface of the iron imparts most of the offensiveness experienced, and that therefore the term "ferruginous odor" is correct, and as it is impossible to employ iron pipes for this purpose without their surfaces soon becoming rusty, the true remedy is to supply a more cleanly metal, as recommended by Mr. Gurney. That gentleman afterward, in rearranging the ventilating apparatus of the houses of Parliament, employed surfaces of sheet zinc, heated with hot water. The improvement in cleanliness by exchanging zinc warming surfaces for iron was very great, but an equal improvement over the zinc surfaces can be made by the employment of pure block-tin tubes. This is superior to all the useful metals in its power to resist atmospheric influences. In this respect, indeed, it is superior to silver. It is a good conductor of heat, and though its bright surface would prevent its radiating heat well, as claimed by Mr. Gurney for zinc, this is unimportant, as air is not warmed by the heat of radiation, but only by direct contact with bodies warmer than itself.

Recent improvements in the mechanic arts have brought tin-encased lead pipe and solid block-tin pipe largely into use for conveying water in dwellings; its cleanliness and healthfulness strongly recommending it.

I would, therefore, employ pure block-tin tubes, filled with hot water, for warming the air. This would not only warm the air without imparting any odor whatever to it when the apparatus was new, but would continue to do so for a great many years after zinc had become entirely coated with its oxide, or iron had rusted through and through and been many times renewed.

There will be several congeries of tubes in each of the four tempering ducts in the upper story of the ventilating house for warming the air. They will be secured into brass tube heads in the same manner as in the surface condenser of a marine engine. They will stand vertically, and open at each end into steam-tight chambers or chests. Into the upper of these I would introduce steam from the boilers, and from the lower I would draw off the water by appropriate pipes, the valves of which would be situated in the engine-room below.

It will be understood that with this arrangement the apparatus would be a steam-heater, if the extent of the tubular surface was limited to the amount necessary to warm the air by the condensation of steam only; but that if the surface is enlarged to the amount required to warm the air with hot water, the steam will be condensed in the upper chambers and the upper ends of the tubes, hot water filling the remainder of the tubes and the lower chambers. A valve in the pipe through which the water

flows away would control the rapidity with which it was drawn off, and, consequently, its temperature. In ordinarily cold weather this would be a hot-water warming apparatus; but upon any extremely cold day it would become a steam-heating apparatus, as the attendant opened the regulating valve in the drain-pipe.

To decide the amount of warming-tube surface necessary, it is first requisite to consider the subject of

MOISTENING THE AIR.

Water pervades the entire human system; considered mechanically, it performs the functions of a lubricant to all its parts. The ligaments and muscles move freely in their places, because every fiber of them is coated with water. The skin and hair are soft and pliable for the same reason. In all mechanism the lubricant must be constantly renewed, as the surfaces it lubricates are always wearing away, the particles worn off being absorbed by the lubricant and flowing away with it. In the case of the human body we find the lubricating water, the supply of which is kept up by our daily food and drink, working its way gradually to the surface through the skin and lungs to the air, where it arrives loaded with the worn-out particles of our animal nature, and into which it evaporates.

Now the rapidity with which water of a given temperature will evaporate into the air in a state of rest is dependent entirely upon how far the condition of the air in regard to moisture is removed from the point of saturation. And in the case of the evaporation from our bodies, if it is too rapid, the skin becomes too dry, and this again induces too rapid a flow of the water within the system toward the surface, making us uncomfortable, and sometimes ill.

Again: the process of evaporation is a cooling one to the surface from which the evaporation takes place. This is explained by the absorption of the latent heat which occurs upon the conversion of a liquid into a vapor. When, therefore, the evaporation is too rapid we are uncomfortably cold, even though the temperature of the air may be sufficiently high.

On the other hand, if the evaporation is too sluggish, the flow of water toward the surface is retarded, and we are made uncomfortable and sometimes ill in another way; also, if the air is of the proper temperature we are uncomfortably warm, the general feeling being described by the term *sultry*.

It is highly important, therefore, that the condition of the air as to moisture should be maintained, in any system of ventilation, at that which is most comfortable and healthful; indeed, that which is the most comfortable is the most healthful.

Most writers upon the subject of the ventilation of large assemblages say that it is impossible to adjust the condition of the air so that all will be comfortable; that persons whose blood has become thinned by age or illness, or who are naturally thin and cool-blooded, require a higher temperature than those who are young, strong, and full-blooded. Also, that in an assemblage where, as in this case, the same person sometimes sits during the entire session of the day without moving or speaking, and at others exerts himself strenuously in a vigorous speech, he is either too cold or too warm, accordingly as he sits still or exerts himself.

My observations and studies upon this subject, however, lead me to the conclusion that if the degrees of heat and moisture are both properly tempered, *i. e.*, each brought to the average of the most comfortable for all, there will be no complaint. The aged and feeble may feel cooler than the young and strong, but they will be comfortably, not uncomfortably cool. Also, when a member sits quietly in his seat all the day, he will be cooler than when he exercises, but then it will be a comfortable coolness; and when he has greatly exerted himself in an extended speech, in which his deep interest may have led him to become excited, although he will feel warm, it will not be an uncomfortable warmth. *Indeed the question is not whether persons feel warm or cool, but whether they are comfortably or uncomfortably so.*

As a general rule, the only point which receives proper attention in the ventilation of large assemblages is that of the temperature. The air is almost always too moist or too dry, generally the latter in cool weather, even if pure, so that the degree of comfort experienced by each is dependent upon his strength and health. It does not hurt a young, strong, healthy person so much to draw the water out of him too rapidly or too sluggish as it does an old, feeble, or sick person. But the health and strength of the most vigorous man are gradually undermined by any extended persistence in living in air which has either a great excess or deficiency of moisture, and one of the great difficulties about it is, that in nine cases out of ten he does not know why his health has failed.

I would therefore provide for controlling the amount of moisture in the air, so that the exact degree of it desired should be maintained with the same precision as the temperature.

The eminent Professor Henry, of the Smithsonian Institution, in a report on warming and ventilating the Capitol, dated May 4, 1866, remarks upon this point:

"It is evident that the great object of warming and ventilating an apartment in the

winter season is to supply it with pure air of the same degree of temperature and the same amount of moisture as that of an open space in a pleasant time in summer. To fully attain this object is a very difficult matter, but that system of warming and ventilation is certainly the best which approximates the nearest to this desirable condition. The heating of the air and preserving it at the desired temperature is the simplest part of the problem; to remove the impure air and to supply its place with fresh air, without giving rise to unpleasant currents and unequal temperature, is more difficult; to supply the proper quantity of moisture, and to prevent its condensation, is attended with still greater difficulty, particularly when the apartments containing a large number of persons are to be thoroughly ventilated. This part of the general problem is, in my opinion, an essential element of proper ventilation, although it has hitherto received comparatively but little attention in this country.

"The idea is entertained by some, that because the heating of a large volume of air to the required temperature of the room does not abstract the aqueous vapor which it contains, that hence the evaporation from a surface of water is not required to render such air salubrious. It should, however, be recollected, that when the external air is, say, at the temperature of zero, all of its aqueous vapor has been condensed, with the exception of an almost imperceptible quantity, and when this desiccated air is afterward heated to a temperature of seventy degrees, its *capacity*, so to speak, for vapor is so much increased that moisture exhales into it with great energy from all bodies from which it can be evaporated. A rapid current of ventilation of air in this condition constitutes an artificial sorocco. * * * It is true that the supply of the necessary amount of moisture will increase the cost of heating and ventilation, but this is a consideration which cannot in most cases be allowed to weigh against health and comfort."

From the report of Dr. Wetherill, on the warming and ventilation of the Capitol, to which reference has already been made, I extract the following remarks:

"For an atmosphere which shall be salubrious to the inmates of an apartment, the hygrometric condition of the air is as important as its freedom from poisonous or deleterious gases.

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"The evaporation of water from the body is intimately connected with health. The sudoriparous glands, which are constantly secreting their liquid, have a length of tubing which has been estimated at twenty-eight miles. The secretion takes place so gradually that the water ordinarily evaporates as insensible perspiration as soon as it reaches the exterior surface of the skin.

"During severe exercise, exposure to great heat in some diseases, or when the evaporation is hindered by an impermeable covering, the secretion collects upon the exterior of the body in drops of sensible perspiration.

"The total average loss by the lungs and skin in twenty-four hours is almost three and a half pounds of water, of which somewhat more than two-thirds, say two and a half pounds, are furnished by the skin. Of these two and a half pounds only one-sixth is furnished by the vital process of secretion by the sweat glands, for the greater part of the moisture transudes through the skin by simple evaporation. The cutaneous and urinary excretions are, as is well known, vicarious. The evaporation from the skin regulates the animal heat, the body being in an analogous condition to those porous earthen jars in which the inhabitants of tropical climates cool water by the evaporation of that portion which exudes to the surface of the vessel.

"The estimated loss of heat to the body by evaporation per minute is sufficient to raise half a pint of water from the freezing to the boiling temperature.

"For health the body must evaporate a quantity of water within certain limits. The amount evaporated is influenced by the hygrometric condition of the air, and by the state of the body itself. The evaporation is increased by muscular action and by a dry atmosphere; it is diminished by repose and by a moist air.

"If the functions of the skin are interrupted certain diseases are manifested. Among these are affections of the throat, catarrh passing into acute bronchitis, pulmonary consumption, pericarditis, inflammation of the stomach and bowels, dyspepsia, rheumatism, gout, and fevers.

* * * * * * * * *

"The rapidity of evaporation of a body depends principally upon the low relative humidity of the air at a high temperature, and upon the maintenance of this condition in the neighborhood of the body by the action of currents of air. Thus, with too great dryness of the air, particularly at an elevated temperature, and especially if it pass rapidly over the body, there will be a greater degree of evaporation than is consistent with health. On the other hand, in an atmosphere saturated with moisture the evaporation from the body would be reduced to a minimum, and would be practically nothing in such air having the same temperature as the body. Although we may bear with impunity these extremes for a short period, a persistence in such conditions would be fraught with danger.

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"It is certain that the hydration of the air will involve in the winter a considerable expenditure of fuel for a powerful ventilation, but the hydration is as necessary to health and comfort as the warmth."

Dr. Youmans, in his Handbook of Social Science, page 308, says:

"Air changed in temperature by warming without increased moisture, is apt to produce unpleasant feelings and painful sensations in the chest, which are often attributed to too great heat. In very dry air the insensible perspiration will be increased, &c. The objection lies against heated air, no matter how heated. Stoves and air-furnaces, with their red-hot surfaces, are undoubtedly worse for the air than hot-water apparatus, which never scorch it; yet the latter may pour into our apartments a withering blast of air at one hundred and fifty degrees, which may be potent for mischief. The only way that hot air can be made healthful and desirable is by an effectual plan of artificial evaporation."

In the report of Senator Buckalew, to which I have before alluded, he says, (page 4:)

"It follows that the dry and warmed air for supplying rooms of great magnitude must be passed over an evaporating surface of great extent, in case that mode of hydrating it be adopted. Doubtless warming the water would increase the efficiency of the plan. Dr. Antisell recommends spray, or jets of water thrown into the air at a right angle to its current, which would no doubt be an effective and satisfactory mode of accomplishing the object where the necessary facilities can be established, among which space is indispensable. The objections to the use of steam, on an extensive scale, for hydration are the production of noise, and, as alleged, of odor, and its imperfect dissolution in the air before entering the chamber. It passes on with the current of air for some time before it becomes dissolved and incorporated with it, and moisture is deposited upon all surfaces with which the volume of air comes in contact. There is no arrangement for introducing steam into the air passing to the halls; but it was provided for the air directed to the committee-rooms and passages. The plan was not found to work well, and has not been in practice."

Mr. Lewis W. Leeds, the consulting engineer of ventilation and heating for the United States Treasury Department, &c., in a report to the Hon. John Covode, on the ventilation of the House of Representatives, January 13, 1868, says upon this point:

"There seems to be an entire unanimity among all parties as to the necessity for additional moisture. This I think of much importance. I, however, doubt the propriety of allowing the steam to be discharged directly into the fresh-air chambers. There is often an unpleasant smell from escaping steam, and more frequently from the air driven from steam-pipes as the steam enters."

The plan I would propose for moistening the air is, to place in the air-ducts extending downward from the tempering ducts in the upper story of the ventilating house, to the horizontal ducts under ground, a system of water-pipes, also made of pure block-tin, standing vertically, their ends closed, and their circumferences throughout the length of the pipes pierced by a great number of minute holes. The water driven into these pipes with force would spin out of these holes radially from each pipe, filling the entire duct with a fine shower. The air passing through this shower would be moistened, and a valve in the engine-room, regulating the force with which the water was driven into the pipes, would determine the degree of moisture at which the air should be delivered into the building.

There are several methods in common use for designating the degree of moisture of the air, viz:

1. The number of grains, in weight of water, per cubic foot of air.
2. The tension of the vapor in height of a mercurial column.
3. The depth of water there would be on the ground, if all the vapor in the air should be suddenly condensed and fall.
4. The "break" or difference between the wet and dry bulb thermometers.
5. The temperature of the "dew point."
6. The "relative humidity" or per centum which the amount of moisture in the air is of that necessary to saturate it at the same temperature.

The last of these is the most popular method, because it appears to be the general opinion that this expression should be uniform for all temperatures to render the air comfortable and healthful to live in. There does not, however, appear to have been any very exact determination of what this should be, but, with a temperature of 65°, a strong, healthy person is not uncomfortable when it ranges above 50 and below 80; but in the course of some careful observations of the effect upon delicate persons in feeble health I have found them commence to complain when it went as low as 60, and again when it went up to 70; the complaint being, however, that it was too cool with the former degree of moisture and too warm with the latter, although the dry bulb thermometer continued at 65°. With a temperature of 65° and a relative humidity of 65, however, I have heard no complaints; and I find that personally I can sit quiet or exercise in air of that condition with great comfort with indoor winter clothing.

With the entire ventilating apparatus arranged as I would propose, these points can be fixed upon and afterward maintained as may be found desirable by experience:

but I will assume the above temperature and degree of moisture as the base of my calculations for the amount of surface required for warming tubes.

A relative humidity of 65 with a temperature of 65° corresponds with—

$4\frac{1}{2}$ grains of water per cubic foot of air;

A tension of $\frac{4}{10}$ of an inch of mercury;

A depth of $5\frac{1}{2}$ inches of water on the earth;

A break between the wet and dry bulb thermometers of $5\frac{1}{2}$°, and

A dew-point of 52°.

To exhibit the increased capacity of the air for dissolving the vapor of water as its temperature is elevated, the following table is extracted from one by Guyot, quoted by Dr. Wetherill in his report:

Temperature of air.	Vapor in grains per cubic foot.	Temperature of air.	Vapor in grains per cubic foot.
Degrees.		*Degrees.*	
0	0.545	55	4.860
5	0.678	60	5.756
10	0.841	65	6.795
20	1.298	70	7.992
30	1.968	75	9.372
32	2.126	80	10.949
40	2.862	85	12.756
45	3.426	90	14.810
50	4.089	95	17.145

The temperature of the external air in Washington is so seldom below 20°, even in cold winters, that I would limit the surface of the warming tubes to an ability to warm the air entirely with hot water from that degree of coldness, and for colder weather would allow it to become a steam-heating instead of a water-heating apparatus, as already explained.

The lowest degree of humidity of the external air reported by Dr. Wetherill, as found in his experiments, was 1.11 grains per cubic foot. I will assume one grain for the base of calculation. There will then have to be added $3\frac{1}{2}$ grains per cubic foot to give it a relative humidity of 65 when at a temperature of 65°, and as there are 7,000 troy grains in one pound avoirdupois, 140,000 cubic feet of air will require—

$$\frac{140{,}000 \times 3\frac{1}{2}}{7{,}000} = 70 \text{ pounds of water per minute.}$$

The temperature of the water would probably be about 40°. This would have to be warmed up to a temperature of 65°, and be supplied in addition with the latent heat necessary to form it into vapor at that temperature.

To ascertain how much the air must be superheated for this purpose—

Let s = specific heat of air as compared with water = 0.2669
v = volume of air in cubic feet................ = 140,000
w = weight of air in pounds per cubic feet .... = 0.075
t = temperature from which water is raised... = 40°
t' = temperature to which water is raised...... = 65°
l = latent heat of steam at that temperature.. = 1070°
W = weight of water to be absorbed in pounds. = 70°
x = number of degrees the air must be heated above 65°, in order that it may be at that temperature after it has dissolved the moisture.

Then,

$$\frac{W(l + t' - t)}{svw} = x = 27°$$

The temperature to which the air must be raised under the above conditions of the weather before it is moistened would, therefore, be—

$$65° + 27° = 92°$$

Now, to determine the extent of surface required for the warming tubes—

Let P = temperature of water in tubes.. = 192°
T = temperature of air after heating = 92°
t = temperature of external air.... = 20°
C = volume of air in cubic feet..... = 140,000
S = surface of tubes in square feet.

Then,

$$.0045\ C\ \frac{(P-t)\ (T-t)}{P-T} = S; \text{ and } S = 78{,}000 \text{ square feet.}$$

In some seasons of the year there will be days when the external air will be all right as to the temperature, but will be deficint in moisture. In such event both the heating and moistening apparatus would have to be employed, as we have seen in the foregoing that the operation of moistening the air is a cooling one. When, however, the heat is a little in excess and the moisture correspondingly deficient, the moistening apparatus would serve both as a cooler and hydrator, and it is only when the weather happens to be in this exact state that the very prevalent idea that the air may be cooled by jets of water is applicable. When the air is too moist as well as too warm such jets would add greatly to the discomfort experienced. When the relative humidity is in excess in the external air and the temperature too low, merely heating the air may correct both difficulties. I would arrange indicators in the engine-room, such that the engineer would be able to see at all times the exact condition of the air in the halls as to temperature and moisture; and then I would so arrange the controlling valves of the entire apparatus that as he looked at the indicators he could add or remove moisture—elevate or depress the temperature at will, and at once.

When a person enters a building on a cold day in winter, especially if he has been riding, he will invariably repair to a fire to warm himself, if there is one. The most grateful fire one can enjoy under such circumstances, is one that presents a clear, cheerful blaze. Good, dry hickory wood in an open fire-place, having burned long enough to be in a glowing state of combustion throughout, is, I believe, every one's *beau ideal* of a pleasant fire. Such fires might be supplied to the cloak-rooms, but the objection to them would be the constant attention they would require to keep them always in full blaze. Anything less than that would be unsatisfactory, as, if a member came in nearly frozen, he would get warm by the general warmth of the hall before a fresh fire could be brought to the necessary heat-giving condition.

The gas fire-places which have been introduced into the residences of some of the wealthier citizens of New York, within the past three years, fulfill all the requirements of the case in the most complete and elegant manner. When not required the gas can be turned down to an ignition blaze, and the moment any one or more persons wish to enjoy an especial warmth they have only to turn on the gas, when there instantly occurs the most efficient and cheerful fire it is possible to imagine. I would place two of these in each of the cloak rooms.

III. COOLING AND DRYING THE AIR IN HOT WEATHER.

To reduce the temperature and moisture of the air of ventilation in the hot weather in summer is a much more expensive operation than warming and moistening it in cold weather. But, in the warm climate of Washington, the midsummer sessions are always dreaded by members of Congress. During the hot season of July, 1868, the House adjourned on two different occasions at an exceptionably early hour, because it was beyond the limits of physical endurance for the reporters to continue their labors longer in the fervid heat. Members were compelled to frequently leave their places and seek temporary relief in some breezy window. Some members, indeed, refrained entirely from appearing in their seats on those hot days. Of course, the oppression was much increased by the impurity of the air, owing to the faulty ventilation; but there can be no doubt that the comfort and health of the members can be greatly improved by cooling the air when it is so excessively hot, though it be pure and plentiful; and that those composing so important a body as the Congress of the United States should not be made uncomfortable and ill to an extent which every one recognizes as seriously interfering with the business they meet to perform, will, I think, be evident to all, even though the expense of reducing the temperature be greater than it has heretofore been customary to incur for any ventilating process. Some attempts have already been made in this direction, but, like all the features of the present system, the means employed were entirely inadequate to accomplish the end proposed. Thus, two tons of ice were melted in the air-duct leading to the hall of the House during each day, of about five hours—say, 800 pounds per hour. The quantity of air passing through the duct, with the blowing engine running at its usual speed of 42 revolutions per minute, as carefully measured by myself, was 24,300 cubic feet.

The temperature of the ice was, say.. 25°
That of the water of condensation was, say.. 60°
The latent heat of ice is..140°

To determine how much the air would be cooled by melting ice—

Let t = temperature of the ice .... = 25°
t' = temperature of the water of condensation .... = 60°
l = latent heat of ice .... = 140°
s = specific heat of air .... = .2669
w = weight of air per cubic foot .... = .075
v = volume of air in cubic feet .... = 24,300
W = weight of ice melted per minute .... = $13\frac{1}{3}$
x = number of degrees the air would be cooled by the melting of the ice.

Then,

$$\frac{W\,(l + t' - t)}{swv} = x = 4\tfrac{3}{4}$$

As, however, the air thrown in by the present blower is mixed up with that which flows into the hall through the open doors, the temperature of the hall is only reduced about one degree by the melting ice.

The greatest absolute amount of moisture Dr. Wetherill found in the air at the Capitol in his experiments was 8.93 grains per cubic foot; and this was during the prevalence of a rain-storm. The temperature seldom rises above 95°, but it reaches that point often enough to establish the propriety of assuming that as the maximum.

If, now, we suppose the temperature to be 95°, and the moisture in the air at 9 grains per cubic foot, and we wish to reduce the temperature to 85° and not permit the relative humidity to rise above 85°, we must abstract 0.7 grain of water from each cubic foot;

Or,

$$\frac{140{,}000 + 0.7}{7{,}000} = 14 \text{ pounds,}$$

from the whole quantity per minute.

At the moment of the condensation of this water from a vapor into a liquid its latent heat is given out into the air; so that removing the vapor is a warming process, as has already been shown that the addition of it is a cooling one. The additional extent which the air must be cooled to compensate for this latent heat of the vapor is expressed by the formula—

$$x = \frac{W\,l}{svw}$$

Where W = the weight of water in pounds .... = 14
l = latent heat of the vapor .... = 1091°
s = specific heat of the air .... = .2669
v = volume of air in cubic feet .... = 140,000
w = weight of air per cubic foot .... = 0.75
x = the number of degrees the air will be warmed by the condensation of the vapor.

With the above values $x = 6°$.

The entire cooling effect must therefore be equivalent to 16°. This would require 15,000 pounds of ice to be melted per hour, or, say, 37 tons per daily session of five hours.

Coal is cheaper than ice per ton, is more conveniently stored and handled, and one-sixth of the above quantity burned in the furnace of a steam-boiler will produce, through the medium of appropriate mechanism, an equal cooling effect upon the air. I would, therefore, discard the use of ice and employ steam power instead.

Machines are operated by the steam-engine for the manufacture of ice, which produce cold by the pumping off the vapor of sulphuric ether, or of the bisulphide of carbon; these liquids evaporizing rapidly at low temperatures, if the pressure of the superincumbent atmosphere be removed, but the employment of such substances would be inadmissible in cooling the air for ventilation, as a slight leak in even one of the many tubes it is necessary to employ in such mechanism would impair the purity of the air to a decidedly sensible and objectionable extent.

I would therefore employ the steam power to drive air-pumps to compress a portion of the air, making it hot, and while it was under this pressure, cool it down to the ordinary temperature by passing it through tubes surrounded by cold flowing water, employing an apparatus for this purpose precisely like the surface condenser of a steam-engine. This compressed air would then be conveyed to the duct through which the blowers were driving that which did not pass through the pumps, where it would be permitted to expand again to the ordinary atmospheric pressure. This expansion would be a cooling process exactly corresponding in extent to the heating one the air underwent when it was compressed, and by mixing this excessively cold air with the warm air from the blowers, the whole would be brought to the desired temperature.

It is mechanically convenient in a machine of this kind to compress two volumes of

air into one in the pumps. To learn how much such an amount of compression would elevate the temperature, a formula is given by Peclét in his Traité de La Chaleur, tome iii, p. 10, as follows:

Let θ = temperature before compression, (centigrade.)
d = density before compression.
θ' = temperature after compression.
d' = density after compression.

Then,

$$\theta' = (274 + \theta)\left(\frac{d'}{d}\right)^{0.42} - 274$$

In this case,

$$\theta = 35^\circ \ (= 95^\circ \text{ Fahr.})$$
$$d = 1$$
$$d' = 2$$

and consequently,

$$\theta = 139.44^\circ \text{ cent., or } 283^\circ \text{ Fahr.,}$$

and the elevation of the temperature would be 188° Fahr.

When air is heated in a confined space its pressure is increased $\frac{1}{480}$ part with each additional degree. The pressure of the atmosphere being 14.7 pounds per square inch, the pressure upon the pump pistons during the last half of the stroke would be—

$$14.7 + (\tfrac{188}{480} \times 14.7) = 20.46 \text{ pounds per square inch.}$$

Let us say that we will maintain a pressure in our condensed-air cooler of 20 pounds per square inch.

To find how cold the air will be after its expansion, we have

$$\theta = \frac{\theta' + 274}{\left(\frac{d'}{d}\right)^{0.42}} - 274$$

The temperature of the Georgetown water during the hottest weather in summer is about 70°. As I would arrange the cooler so that there would be reverse currents of cold water and hot air, the latter would be cooled down to say 75°, which corresponds with 23.89° centigrade.

As the heat was abstracted from the air it would be further condensed $\frac{1}{480}$ part with the departure of each additional degree, the pressure being maintained; hence we would have

$$\theta = 23.89$$
$$d = 1.$$
$$d' = \frac{14.7 + 20.}{14.7.} = 2.36$$

Whence—

$$\theta = -66.12^\circ \text{ cent. or } -87^\circ \text{ Fahr.}$$

This would be a reduction from its original temperature of 182°. This being slightly more than ten times the amount of cooling force, it is necessary to apply to the whole quantity of air furnished one-tenth of that amount, or 14,000 cubic feet will require to be passed through the pumps. Allowing 10 per centum for loss, the dimensions of the air pumps will require to be as follows:

Number of pumps	2
Diameter of pistons	63 inches.
Stroke of pistons	6 feet.
Double strokes per minute	30

As the mean resisting pressure will be 12.4 pounds per square inch, the net power required to work them will be 900 horses. Allowing 10 per cent. for friction of engine and pumps, and we have 1,000 horses as the gross effective power of the engines. I would attach the steam and pump pistons to the same rods; with this arrangement the steam cylinders would have to be 45 inches diameter. I would employ a steam pressure of 40 pounds per square inch, and cut-off at one-fourth from the commencement. A surface condenser would be attached, and the mean gross effective steam pressure would be 29 pounds per square inch.

If the air was simply conveyed to the air duct and mixed with the warm air from the blowers, it would be cooled down below the desired temperature, and a portion of the moisture it is desirable to abstract would be condensed in the form of a fog and carried along with the air into the hall, which would thus be filled with a cold damp air, highly objectionable. It is necessary, therefore, to have the cold air introduced in a peculiar manner, such that not only may the moisture be abstracted, but that the exact amount removed may be subject of convenient and easy regulation by the engineer in the engine-room. The character of this regulation must necessarily be that the power exerted by the engine shall determine the extent of the cooling force, and that the

amount of this which shall be devoted to reducing the temperature of the air, and that which is devoted to abstracting the moisture, shall be subject to a regulating lever, or hand-wheel; so that if the engineer moves this in one direction the air will be made cooler and more moist, and if in the other it is made warmer and drier, the cooling engine continuing to run at the same rate.

To accomplish this I would erect in each of the cooling and drying chambers of the tempering ducts a congeries of tubes, somewhat similar to those employed for warming the air in cold weather, only I would have an additional chamber or chest at mid-height, so that there would be, in fact, two systems of tubes, one above the other; in other words it would be two stories high. Now, in the two upper chambers I would have openings in the bottom in all the spaces between the rows of tubes; these openings controlled by valves, and the valves appropriately connected with hand-levers, or wheels, in the engine-room; there being one for a system of valves which would control the openings in every third space between the rows, and one for the remaining spaces. The aggregate area of the openings in the lesser system should equal the area of the pipe which brings the compressed air from the cooling-engine; those in the other spaces, being of the same dimensions, would have in the aggregate twice this area. Then the compressed air should be conveyed by a pipe from a reservoir attached to the cooling-engine, to the lowest chamber; thence it would flow upward through the tubes into the upper chambers, then downward through the openings into the spaces between the tubes. The operation of this arrangement would be as follows:

Let us imagine a condition of the external air such as has been assumed for a maximum performance of the cooling-engine. In this case let the openings in two-thirds the spaces between the tubes be closed and those in the remaining spaces be wide open, the area of the whole being such that it would require a pressure of twenty pounds per square inch to drive all the air supplied through them. It will be perceived that the pressure throughout, from the pumps to the exit, will be 20 pounds per square inch, and that therefore the temperature will be maintained at 75° while the air passes through the tubes. As the compressed air pours down between the two rows of tubes and expands to the ordinary atmospheric pressure, its temperature will fall so suddenly that the moisture within it will be condensed and part of it frozen into minute hail. The main portion of the air from the blowers will pass through the remaining spaces between the tubes, and as they are only one-eighth of an inch apart in the rows, they form, in effect, walls of separation between the warm and the cold air. A sufficient quantity of the air from the blowers will, however, pass into the cooled spaces to carry forward the hail storm raging there, and as the hail and condensed moisture are carried along the narrow spaces they will come in contact with the surfaces of the tubes and be deposited upon them. The temperature of these will be too low to vaporize the moisture, but warm enough to melt the hail, and the water will run down them as it does along the sides of an ice pitcher, to the bottom tube sheet, whence it will pass off in proper drains prepared for it. With this arrangement one-third the moisture in the air may be removed when required by the lesser system of valves only being opened, and when less than this proportion requires removal, as will be almost universally the case, it can be governed with exactness by opening or closing more or less the remaining valves. As the air issues from the dryer it will be in vertical strata of cold, dry, and warm moist air, in the proper proportions, both with regard to temperature and moisture, to give the desired condition when they are mixed, which they will soon become as they pass along the duct. When, however, the external air is of the right temperature, or not much above it, but is so damp that it must be dried, the resulting temperature of the mixture will be too low, in which event it must be warmed up to the desired point as it passes through the heater. On the other hand, the external air may be so dry that when it is cooled down to the desired temperature it will still be too dry; when this occurs the moistening apparatus must be put in operation. Indeed, as has already been explained, it will sometimes happen that moistening the air will sufficiently cool it.

To enable the engineer in charge to control the condition of the air he delivered to the hall I would arrange pipes about three inches in diameter, and properly incased with a non-conductor of heat from the inlet duct and from the tempering ducts just beyond the moisteners, leading them through a convenient place in the engine-room for observation to the suction openings in the blowers, which would cause a rapid flow of air through them, having the exact condition existing at the other ends of the pipes. Into each of these pipes as they pass through the engine-room I would insert the wet and dry bulbs of a hygroscope, which should plainly indicate the temperature and degree of moisture in the air passing through the pipes.

The method here recommended for drying the air when it is too moist, or when it is made so by reducing its temperature, is simply the adoption upon a small but sufficient scale of that employed by nature in effecting similar changes of weather.

Dr. Metcalf, in his incomparable work on caloric, vol. i, p. 267, and following, describes and explains the influences exerted by the vapor of water upon the atmosphere and how it is added and removed. I quote from him as follows:

"As the phenomena of lightning have been universally known to be immediately

connected with the production of rain, it becomes necessary to ascertain with certainty the cause of evaporation and condensation before attempting to solve the problem of atmospheric electricity.

"That caloric is the true and only cause of evaporation, or the formation of steam, is one of those self-evident propositions which would seem to require no proof. But to remove all doubts upon the subject the fact has been experimentally demonstrated by Dr. Dalton, to whom the science of chemistry and meteorology is so largely indebted.

"He put a little water in a dry glass flask with a thermometer in it, when he found that a small quantity of vapor was formed at 32° Fahrenheit. At 40° the amount was increased; at 50° it contained still more vapor; while at 60° the quantity was yet further augmented. He also found that when the temperature of the flask was suddenly reduced from 60° to 40°, a portion of the vapor was converted into water, and that the quantity retaining the elastic form was precisely the same as when the temperature was originally at 40°.

"The above is a simple and beautiful representation of what is perpetually going on throughout the atmosphere and the steam-engine.

"By another series of admirable experiments he ascertained that the quantity of water evaporated in a given time was exactly in proportion to the elastic force of vapor at the same temperature, whether formed in vacuo or under the pressure of the atmosphere, with this difference, that in the latter case the process goes on much more slowly, because the atmosphere presents a mechanical impediment to its diffusion somewhat analogous to the obstruction of water by porous sand. From which he inferred that vapor is not chemically united with the air as has been formerly supposed, but mechanically diffused through it, forming a distinct atmosphere of its own, the elastic force of which is always in proportion to temperature.

"At 0° he found the elastic force of vapor equal to the pressure, .064 inch of mercury, that is, about one-fifteenth of an inch; at 32° it amounted to one-fifth of an inch; at 47° about one-third of an inch, or .339; at 59° .507, or one-half an inch; at 80° one inch; and at 90° 1.360. He also ascertained that the elastic force of vapor at 212° is equal to the pressure of the whole atmosphere, or 30 inches of mercury. (Manchester Memoirs, vol. v.)

"From the above experiments it follows that if the temperature of the earth were 80° from the equator to the poles, the quantity of vapor would be everywhere the same, and equal to about one-thirtieth of the average weight of the whole atmosphere; but that if its temperature were reduced from 80° to 59°, one-half the vapor would be precipitated in the form of rain; if to 32°, four-fifths of it would be converted into snow; and if reduced to 0°, 14 out of 15 parts of the whole would descend to the earth in the form of ice, in obedience to that universal law of nature by which bodies cohere and tend toward a common center.

* * * * * * * *

"If at the temperature of 80° the atmosphere contain an amount of vapor equal to the pressure of only half an inch of mercury, while it is capable of sustaining twice that quantity, it will require a reduction of temperature below 59° to cause precipitation. Hence it is that the atmosphere often undergoes great reductions of temperature without producing rain. But when the air is full of vapor the process of evaporation is arrested, which explains why a cold dry air is more favorable to evaporation than warm air that is already saturated, especially if the former be in a state of rapid motion.

"Dr. Dalton found that when boiling water was exposed to a current of air that carried off its vapor as fast as formed, vaporization went on a third faster than in a room where the air was still. Hence it is that the northeast and east winds, which in the west of Europe are generally dry, and far below the point of saturation, seldom condense the vapor of France and England; but, on the contrary, often redissolve the clouds already formed, producing clear weather. During summer, when the atmosphere has been for some time comparatively still, it is soon saturated with vapor, which is indicated by heavy dews, and the formation of clouds termed cumuli, in which case the weather becomes hot and sultry, because the caloric which is usually carried off by evaporation and winds accumulates on the surface of the earth, and heats the superincumbent air. Such a state of things generally forebodes an approaching thunderstorm.

"That the condensation of atmospheric vapor is owing to the abstraction of its caloric by colder currents of air is evident from the fact that in the tropical ocean far from land, where the trade-wind blows steadily in one direction, and where the temperature seldom varies more than two or three degrees, there is less rain than in the vicinity of the continents and large islands where currents of air of different temperatures frequently meet.

"In the great desert of Sahara there is scarcely any rain, because the wind blowing over it is generally in the same direction, while the vapor transported by it from the ocean is still further rarefied by the intense heat reflected from the scorching sands where there are no mountains to arrest its progress. There are also long droughts in

Egypt, Palestine, New Holland, and many other parts of the world, where the winds blow long in one direction without encountering colder currents. During summer in the United States the atmosphere is often so much heated that the vapor brought from the ocean by southern winds is not condensed for several weeks, and sometimes two months, but is further expanded until it becomes saturated, or meets with a current from the northern points of the compass, when thunder gusts follow.

"When I come to treat of winds it will be shown that the most extensive falls of rain in the middle latitudes are produced by the meeting of immense masses of air from opposite quarters of different temperatures, as during the equinoctial floods and storms. When both contain as much vapor as they can support at their respective temperatures, the amount of precipitation is of course the greatest.

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"By a careful analysis of the phenomena, it becomes self-evident that, *if caloric be the true and only cause of evaporation, condensation and precipitation can be effected only by the evolution of the same agent.* During winter the quantity and elastic force of vapor in the atmosphere are comparatively low in the middle latitudes, where it is condensed gradually on meeting with colder air. During spring evaporation augments with increase of temperature, when masses of warm and cold air often meet, causing frequent showers of rain and sometimes of hail, still without much thunder and lightning. But during summer, when the temperature becomes tropical and the atmosphere saturated with highly elastic vapor, we have tremendous explosions of thunder and lightning, with rapid precipitations of rain and hail."

It appears conclusive from the foregoing remarks of the learned writer that the mechanical arrangement I have described for cooling and drying the air, when it is very hot and sultry, is only wanting in magnitude to produce a regular thunder-storm in the air duct. The electricity will probably be evolved in precisely the same manner that it is in the heavens when very cold and very warm currents of air are brought suddenly together, but it will be on so comparatively small a scale that the observable phenomena of the thunder-storm will not be apparent.

It is reasonable, however, to expect that the same pleasant effect would be had upon the air that a thunder-storm has, viz: to give it a peculiar freshness, as if it had been washed clean, and as if it possessed renewed vital powers, giving every one elastic spirits and additional life and strength.

Since the discovery of ozone by the late celebrated German chemist, Schoenbein, it is generally supposed that the electric fluid developed during thunder-storms gave that condition, in considerable degree, to the oxygen of the air, and that its delightful freshness and invigorating character, as experienced after a thunder-storm, were due to this cause, ozone being a condition of oxygen which causes it to enter into chemical union with other substances with greatly-increased avidity. When, therefore, we breathe air of which the oxygen is in this condition, or which is impregnated with this principle, it unites, with an increased readiness, with the carbon and hydrogen, which pass into it out of the blood through the membranes of the lungs.

There is also good reason to believe that cooling the air by first compressing it, as I have recommended, will have the effect of developing ozone. Dr. Wetherill states in his report, to which I have several times alluded, (p. 91,) that—

"M. Saint Pierre (Comptes-Rendus, l. viii, 420, 1864,) discovered a remarkable production of ozone, by the action of certain kinds of ventilating apparatus. He found that test paper placed in the tuyere of a blast-furnace gave evidence of ozone in a much stronger manner than when in the external air. And to show that the velocity of the current, bringing greater quantities of the air to the paper, was not the cause of the reaction, he placed, at the same time, similar papers upon the governor of a steam-engine in a saw-mill. From these, and other experiments, he concludes that the reaction arises from compressing the air."

Whether this desirable condition of the air would be imparted to it by the mechanism described, or not, there can be no doubt but the temperature and moisture of the external air could be modified, by the system I have recommended, from its most unpleasant condition, in any season of the year, to that which is most delightful, and without imparting to it any impurities or unpleasant odors.

To supply the necessary quantity of steam to the blowing and cooling engines, and for warming the air in cold weather, I would provide three boilers, the aggregate potential dimensions of which would be as follows:

	Square feet.
Grate surface	135
Heating surface	6,750
Calorimeter through tubes	27

COST.

I have carefully ascertained how much it will cost to carry out the foregoing programme, and, although it amounts to a larger sum, in the aggregate, than I find contemplated in any of the various reports which have been made on this subject, it is

very much less than was expended by the British House of Commons upon improving the ventilation of their hall, though it has the addition of the cooling and drying apparatus, the cost of which is a material addition to the expense; and, moreover, draws its air from an unobjectionable locality, while the air for the House of Commons is drawn through the side windows of the basement story, which, on one side overlook the court-yard where the carriages come for the members. The smell, as of an unclean stable, became so offensive that orders had to be issued that horses should not stand there when waiting. On the other side the windows overlook the Thames, and orders had to be issued in this direction against the passage, near the building, of barges filled with offal. I do not know the exact amount they have expended, but the following extract from the evidence of the Hon. E. P. Bouverie, M. P., a member of the House committee on ventilation, before a committee of the House of Lords, May 12, 1854, will give an idea of it:

"Question 762. Do you not think that Mr. Gurney's improvement in the ventilation of the house is mainly attributable to the windows being open?

"Answer. I have heard it said that the result of our spending £200,000 in the ventilation of the House of Commons has been to prove that the best way of ventilating the room is by opening the windows. We sit in the house a good many hours after the windows are shut; for instance, we did so last night, and the air, I think, remains very fresh and good."

Here is an expenditure of $1,000,000, in gold, with labor and materials so much cheaper than in this country that it would require $2,000,000 of our present currency to effect the same work here now, and even then they had not arrived at a fully satisfactory condition of their hall, as they made several changes subsequent to the above date.

The whole cost of the Capitol building, up to the present time, is about $12,000,000, and it is correspondingly grand in its conception and beautiful in its detail. The materials are of the highest order ever employed in building, and they are brought together with an exquisite taste and skill, which is probably unsurpassed in any edifice in the world.

The new wings are so arranged that mechanical ventilation is the only proper method, and that was adopted and is now in use. But the mechanism is utterly inadequate in its dimensions and power, is arranged upon erroneous principles, and is faulty in every detail of its design. It propels a feeble current of air up through the door of the halls near the western ends, which current continues upward and out through the ceilings, without having done much to ventilate anybody. In winter it is heated by rusty iron steam-pipes, without being moistened, and in summer the little ventilation there is may be said to depend upon the open doors.

Such a system in such an edifice is simply disgraceful. How much honor is reflected upon the nation by imposing colonnaded façades of purest marble; by grand corridors with tessellated floors, bronze doors, and frescoed walls; by great dimensions, or gorgeous gildings, and other ornaments, if the whole is kept filled with a mephitic atmosphere by a defective and deficient ventilating mechanism?

The conception of the ventilation of such an edifice should be as complete and superior in its character, as a scientific and mechanical work, as the building itself is as an architectural one.

The mechanism should be indebted for the principles which govern its arrangement and operation to a correct application of known physical laws. It should be scientifically proportioned throughout all its detail, that it might correspond with the building and with the work it had to perform.

Each part should represent the highest skill in the arts to which it pertains in its design, its material, and its workmanship and finish.

As in carrying into execution the plan I now propose, the Architect of the Capitol will be called upon to erect a ventilating house, in which to place the necessary machinery and apparatus, it would be entirely within his province to excavate for and construct underground air-ducts and to reconstruct air-ducts within the building. I would therefore confine myself to furnishing the following, which I will do at the prices named opposite each item, to wit:

One pair of surface-condensing engines of 250 horse-power, for driving blowers, with wood gear fly-wheel; all erected in place complete	$17,630
Four blowers for the House of Representatives, each having a capacity of 80,000 cubic feet per minute. Four blowers for the Senate, each having a capacity of 60,000 cubic feet per minute, with shafting, hangers, gearing, pullies, belts, &c., all erected in place complete	13,200
One pair of surface-condensing engines, of 1,000 horse-power, and connected thereto a pair of compressing air-pumps of sufficient dimensions to absorb the above power when compressing air to a pressure of 20 pounds per square inch above the atmosphere, and connected with these pumps a tubular compressed air-cooler, having 3,000 square feet of brass tube surface, all erected in place complete for cooling and drying the air in hot weather	108,000

Drying apparatus, having 7,750 square feet of block-tin tubular surface, with regulating valves complete, for renewing the moisture from the air when it is too damp, or when it is made so by having cooled it, all erected in place..	$49, 170
Heating apparatus, having 78,000 square feet of block-tin tubular surface, with steam and water-pipes, and valves complete, all erected in place	246,000
Three boilers and their appurtenances, having in the aggregate 135 square feet of grate surface, and 6,750 square feet of fire surface, and capable of generating steam for 1,250 horse-power, and of sustaining a working pressure of 50 pounds per square inch above the atmosphere, all set in place complete, with copper steam-pipes to engines........	36, 370
Moistening apparatus, made entirely of block-tin pipes, and equivalent to 70,000 square feet of pan surface, all erected in place, with valves, &c., complete........	11, 580
Extra ceilings of plate glass and iron of double thickness, extending over the entire halls; rearranging the gas fixtures over new ceilings; perforating the ceiling for the passage of the air into the halls, and supplying wire-screen deflectors to distribute the air equally over all parts of the ceilings; all complete and in place........	128, 300
Wire-gauze fitted to backs of seats in galleries for passage of foul air through floors of galleries, perforated plates fitted to cornice of front of galleries for passage of foul air, and to prevent the exhalations of persons leaning over it from passing down to Senators and members on the floors of the halls, and additional registers in the floors of the halls so that there shall be at least one to each desk........	19, 910
Sixteen gas fire-places, with marble mantles complete, in the cloak-rooms; new registers in cloak and committee rooms and corridors........	19, 000
Indicating air-pipes, hygroscopes, Hotwell thermometers, steam cylinder indicators and fixtures, engine counters and clock for engine room........	4, 880

RECAPITULATION.

Blowing-engines........	$17, 630
Blowers........	13, 200
Cooling-engines........	108, 000
Drying apparatus........	49, 170
Heating apparatus........	246, 000
Boilers........	36, 370
Moistening apparatus........	11, 580
Extra ceilings, &c........	128, 300
Wire-gauze, registers, &c........	19, 910
Gas fire-places, &c........	19, 000
Instruments........	4, 880
Total........	654, 040

The work remaining to be done by the Architect will be as follows:

First. The construction of a suitable ventilating house in the western park for the reception of all the boilers, engines, blowers, heaters, dryers, moisteners, &c. It should be 75 feet long by 50 feet wide, have two stories and a basement. The blowing-engines, cooling-engines, and the blowers would occupy the ground floor; the dryers, heaters, and moisteners the upper story; and the coal and boilers the basement. The boilers themselves would be placed in a recess on one side 30 feet wide by 36 feet long, so as to be under a pavement only, that, in case of an explosion, the building and the machinery within it might not be injured. The upper story of this building will contain four temporary air-ducts extending longitudinally the entire length, and 8 feet wide in the clear. It is in these that the heaters, &c., will be placed, the air being driven up from the blowers into one end and escaping into the supply air-ducts at the other. Each story, and the basement of this building, should have a height in the clear of not less than 15 feet. On the top of the building there should be a tower at each end, to serve as inlet-ducts. They should each have a cross area of 40 square feet. The height of these towers may be such as to render them visible or not, as the Architect may elect.

Second. The construction of air-ducts from the ventilating house to the space above the ceiling, at each end of each wing, making four ducts for the conveyance of pure air, one from each tempering chamber. Each of these ducts must have a cross area of 20 square feet in the direction of the House of Representatives, and 15 square feet in the direction of the Senate, and must be distinct from each other during their whole length.

Third. The conversion of the space beneath the floor of the halls into one chamber, it being now a complicated system of air-ducts.

Fourth. The construction of air-ducts from each end of each of these chambers to the ventilating house, making four ducts for foul air, each one will communicate with an exhaust blower. These foul-air ducts must be of the same dimensions as those which convey the pure air, and must also be kept distinct from each other during their whole length.

Fifth. The construction of a foul-air and smoke conduit from the ventilating house to the base of a chimney which shall be situated without the grounds. This conduit must have a cross area of 96 square feet. I would introduce the smoke from the boilers to the center of this conduit, and thus the foul air from the blowers would act upon it in the manner of the syphon ejector, and maintain a force draught through the boilers, which will insure their invariable efficiency. In the construction of all these air-ducts it is important that the areas be not contracted at any part, because the power required to furnish a given quantity of air in a given time must be doubled if the velocity is doubled, and I have computed the power required upon the basis of the areas above given. It is also important that when the direction is changed, it should, for obvious reasons, be curved as much as the circumstances will permit. Those ducts which convey the pure air upward within the buildings may, in the south wings, be situated back of the grand stairways. In the north wing they should occupy the southwest and southeast corners of the wing. The foul-air ducts can occupy at the western side the same position as the present pure-air ducts, and on the eastern side similar ones can be provided.

Sixth. The construction of a chimney in some locality out of the grounds, having a cross area of 96 square feet.

Seventh. Introducing a Potomac water-pipe, of not less than six inches internal diameter, into the ventilating house, and providing a drain of equal capacity from the building.

The foregoing work, executed in a thorough, first-class manner throughout, will result in a ventilation of the Capitol which will elevate it to the position of being the grandest public building in the world.

The peculiar feature of having the halls surrounded with inclosed corridors, now so generally condemned, will be appreciated for its convenience, and for the very fact of the impossibility of any interference of the weather on the outside with the delightful air which will be constantly maintained within. It is only occasionally that nature gives us the pleasantest condition of the atmosphere for weather, and when she does, how everybody salutes his friend by reference to the charming day! How thoroughly we all appreciate it! How it elevates the spirits and invigorates the health! What I propose is to make the weather within the building charming all the time.

ACOUSTICS.

There will be another feature of marked superiority developed by the adoption of this plan of ventilation, and that is, the acoustic properties of the two halls. These are now very bad and are justly condemned, though I do not consider that the fault lies in the architecture. Indeed, few halls are so well designed in this respect.

In a hall where each of the audience becomes in turn a speaker, it is essential that dependence for audibility shall rest entirely upon the direct transmission of the sound from the mouth of the speaker to the farthest listener. If the speaker were always to occupy a given position, then the walls and ceilings could be so constructed in regard to form and materials that the sound would be reflected in a manner to assist the direct force of the voice, but this is impossible where the speaker may occupy any part of the floor; and in such case, care must be taken that there are no reflections of the sound, as, except the various reflected rays and the direct rays of sound arrive at the ear of the listener at about the same time, it causes confusion and fatigues the listener. These appear to have been the ideas of the architect when he designed the halls. The trouble now is the imperfect transmission of this direct ray of sound from the speaker to the listener.

When it is remembered that sound is transmitted by verberations of the air, it is easy to understand that currents moving in different directions about the halls, or inequalities in the temperature and consequent density of the air in different parts, through all which the waves of sound must pass, would so disturb such waves that by the time they reached the ear of the distant listener they would be greatly broken and neutralized, and the clear, distinct articulations uttered by the speaker would in consequence be so jumbled and mixed up that what he is saying can only be determined with difficulty.

In the system of ventilation I propose, the air enters through all parts of the ceiling with uniform force, and by the time it has descended ten or fifteen feet it has become a tranquil stream, slowly descending in a quiet mass. When a speaker sends his voice through this quiet air, the waves of sound will cross the entire hall without being broken or confused, and the utterances of the speaker will be conveyed intact to the ear of the listener, mellowed and softened only by distance.

Throw a pebble on a calm day into the middle of a deep flowing river having a slow current, and you will see the waves from it preserve their circular form and their distinctness until they are broken on the banks, but let a breeze ruffle the surface of the water, or let rocks beneath disturb the current, and the waves from your pebble will extend but a short distance from their source before they will be broken up and disappear; and so it is with the passage of sound through the air; eddies and counter-currents interfere at once with it, and unless it is more powerful than these disturbing causes it is destroyed in a short distance. As now ventilated, every speaker must pitch his voice much higher and give it much more force, and every listener must give more careful attention to what is being said, than will be necessary if my plans are executed. Indeed I feel confident that all complaints against the acoustic properties of the halls would cease at once this went into operation.

PROPOSAL.

I am prepared to enter into contract and furnish satisfactory sureties to execute the foregoing work in full accordance with the letter and spirit of this proposition for the hereinbefore said sum of $654,040, in eighteen months' time; payments 5 per cent. of the contract price monthly during the progress of the work, until 87½ per cent. shall have been paid, the final 12½ per cent. to remain unpaid until August 1st, 1872, when it shall be paid in full unless a resolution shall have passed Congress to the effect that the work is unsatisfactory.

I am, very respectfully, your obedient servant,

ALBAN C. STIMERS.

Hon. JAMES W. NYE,
Chairman Joint Select Commitee on Ventilation and Acoustics.

OFFICE OF ALBAN C. STIMERS, NAVAL ENGINEER,
No. 45 *William Street, New York, May* 2, 1870.

DEAR SIR: Agreeably to your request that I would suggest such a course of experiments as would determine with scientific accuracy the exact character of the present ventilation of the halls of Congress, I beg leave respectfully to offer the following:

The theory of the present system is, that a sufficient supply of fresh air is forced into the halls through the floors by means of fan blowers in the sub-basements driven by steam-engines; the air from these blowers passing through single main ducts to the height of the floors, and then distributed throughout the area of the halls by smaller ducts, leading in different directions to all parts, the air rising from them through registers placed in the floors. From these registers the air is supposed to rise vertically, ventilating the people as it ascends to the ceilings, which are perforated for its egress.

Now, *if* the quantity of air supplied by the blowers was ample; *if* it was equally distributed throughout the floors and galleries of the halls; and *if* it rose vertically from each point of ingress to the perforated ceiling, there could not exist the foulness now so evident in certain parts of the halls. I would therefore recommend that the following facts be determined:

1st. The gross quantity supplied by the blowers.
2d. The per centum of this quantity which enters at each register.
3d. The direction the air takes from each register.
4th. How long it takes the air from each register to reach the ceiling.
5th. The condition, as to foulness, of various parts of the halls and galleries.

The foregoing should be ascertained with different conditions of use, such as when there are many people and when there are few, and indeed when there are none; when the doors are kept open above and below, and when they are kept shut; when the doors are kept open on a calm day and when on a breezy one. Such a series, well conducted, would, I think, give a very clear indication of the causes of complaint and would explain the acoustic difficulties as well.

To arrive at the velocity and direction of currents, I would employ toy balloons. By attaching to each one an open envelope it will be convenient to weight this with sand until the specific gravity exactly corresponds with that of the air, and the envelope can be marked with a number, or otherwise, for its identification. By placing one of these over a register it will pass with the air to wherever this flows, lodging finally at the point of egress. By starting a number of these at the same time from various parts of the floors and galleries, a very striking impression would be made to all observers as to the currents going on within the chambers.

For a proper scientific record, however, there should be only one at a time, or not more than can be accurately watched by special observers. These should be properly stationed, with diagrams of the chambers before them, and should mark on these dia-

grams the course of the balloons, marking the positions they occupied at the end of each minute. From these, general diagrams could be drawn which would indicate the currents under the different circumstances obtaining at the times of the observations.

To determine the per centum of the whole quantity of air which should enter at any given point, I would start a balloon at the register and note the time of its passage through a given short distance, say two feet, and multiplying the velocity thus found by the area of the openings in the register, the amount admitted there would be found. To measure with accuracy the short periods of time this would require, I would employ a clock which was provided with a moving strip of paper, the paper moving with a given known velocity, say two inches per second; a pointer held down upon this with the finger, during the desired period of observation, would make a mark on the paper the length of which could be accurately measured. Such a clock would cost not exceeding $60.

To determine the foulness of the air at various points of the floors and galleries, I would do it by determining the amount of moisture of each point, and compare this with that contained in the inflowing air.

The average man requires 6 cubic feet of air per minute to absorb the moisture which emanates from him, while he only requires one-quarter of a cubic foot to absorb the carbonic acid gas of the breath.

Moreover, the carbonic acid gas in the exhaled breath is not the cause of foul smells, but the moisture which emanates from the person is loaded with worn-out animal matter, which, though not immediately offensive, if from a clean, healthy person, soon becomes so. To measure the additional amount of moisture at any given point is, therefore, to determine the foulness of the air at the same point. This can be done by the careful use of hygrodeiks, which can be placed upon the desks of members and on the seats in the galleries. These cost $15 each, and a dozen of them would suffice.

The toy balloons are prepared every morning here in New York by persons who gain a livelihood by selling them on our streets in the afternoon. People buy them for the amusement of their children on their way home. It will be necessary to carry a man with his apparatus to Washington, as they have to be refilled every morning, the gas always oozing out in a few hours. The expense of these would be small, the man being employed as an assistant.

I think the foregoing, properly executed and reported upon, the report illustrated with the diagrams indicated, would add a fund to our information on this subject, the value of which would exceed its cost many times over, as whatever may be accomplished by heating, cooling, moistening, and drying the air of ventilation by superior methods, it avails nothing unless the air is *constantly renewed in every part of the vast halls.*

I would recommend that the committee appoint a competent person to carry out the entire programme and report to it the results obtained.

I am, very respectfully, your obedient servant,

ALBAN C. STIMERS.

Hon. THOS. A. JENCKES, M. C.,
House of Representatives, Washington, D. C.

MR. LUTHER ROBINSON'S PLAN FOR VENTILATING THE WINGS OF THE UNITED STATES CAPITOL.

No. 46 CONGRESS STREET, BOSTON, *June* 10, 1870.

To the Congressional Committee on Ventilation, Washington:

GENTLEMEN: The failure of most attempts to secure the satisfactory ventilation of buildings clearly proves that they have been made without regard to the true principles, on the right application of which, alone, success depends.

All simply "ejecting" plans, with or without the aid of heat, are wrong in theory; and are, therefore, as proved by universal experience, inefficient and unsatisfactory in practice; and all forcing plans are costly, for machinery, power, and care, even if excellent results *can* be secured, and, as to results, I have seen many cases of failure, and none of marked success.

The philosophical reasons for their failure it is easy but not necessary now to state.

It is not my present purpose to write a general essay on ventilation, nor to correct, describe, or discuss, unless briefly and and incidentally, the various theories on this subject, nor even to recall to your minds the several interesting collateral questions often and properly discussed in this connection, presuming all these to be as familiar to the committee as to myself.

My purpose is, rather, to propose a definite *practical* plan for securing, *beyond the possibility of failure*, a highly satisfactory condition of the atmosphere in the legislative halls in the Capitol in Washington.

After full and careful study of the philosophy, operation, and results of all systems

in use in this country, and with an experience in ventilating many hundreds of buildings, small and large, with the most complete success, without an approach to a failure—in the last six years, at least—I can speak on this subject with the confidence of knowledge not merely theoretical.

I have fully considered the construction and circumstances of your legislative halls, and know precisely what is needful to make their atmosphere constantly fresh and comfortable, and shall offer to ventilate one or both of them, in accordance with the general plan herein indicated, executing all mechanical work in style and manner entirely satisfactory to the committee, after examination; also, SECURING and WARRANTING *results* entirely satisfactory after a reasonable trial, on terms to be named in separate, more detailed specifications and proposals, soon to be made.

The proper ventilation of the Capitol, as of other buildings, requires the furnishing of an abundant supply of fresh air, its proper distribution, and the effectual removal of air from the building.

By the system of ventilation which I have orally explained to you, all of these objects are satisfactorily accomplished.

Beyond all doubt, fresh air is furnished, and impure air efficiently removed, and, with proper skill in the application of the system, without annoyance from currents.

To the roofs of buildings we apply structures of iron or other material—*ventilators*, of peculiar construction, having mouths open in every direction, subdivided by several partitions, with tubes, straight or angular, long or short, as needful, subdivided to correspond with the divisions of the ventilators, extending through the upper portion of the building, and reaching proper points in the ceiling of the room to be ventilated. We thus establish communication, through numerous passages, between the room and the external air.

Through these ventilators and connecting tubes *alternating currents of air pass*. Through some of them fresh air passes in, and is properly distributed, while through others impure air passes out, securing thus the real, efficient, quiet change of air, which constitutes good ventilation.

This is not theory, but fact, easily ascertained by intelligent examination of any one of the thousands of these ventilators already in use; and the results of the change are manifest to the most casual observer.

Over the Capitol, and within ten feet of its roof, an abundance of air passes, every day in the year, to ventilate, even excessively, more than a score of such buildings. It moves with a momentum varying with its velocity, but ever sufficient for our purpose.

We use this undoubted "power of the air" as one of two forces to accomplish our end. Whatever its velocity or direction, it presses against some face and into some mouth or mouths of these ventilators, and is conducted through some of the tubes to the room, as surely as water and illuminating gas, under pressure, are driven through their pipes to distant points for convenient use.

The necessary consequence of this influx of air is condensation, if the room is tight, or exit if not tight. But with the construction described there *can* be no condensation, as some faces under the lee must be less pressed than those against which the wind blows, allowing easy exit to the air driven out in consequence of the entrance of air on the opposite side.

This operation is visible to all who, on a frosty day, pass any of the three hundred drying and dressing rooms on which these ventilators are used.

From three rooms of this class, under control of members of present Congress, moisture enough has already been removed to form, when condensed, not less than forty thousand barrels of water.

The ordinary heat of a room, from whatever source derived, acts as another motive force, establishing and keeping up this same alternation of currents, even without the aid of wind.

Heat drives air through some of these passages, and not through all of them, while external air, even by its weight alone, falls in to supply its place.

This is a demonstrable *fact*, which no argument can make more plain, nor any theorist disprove.

Thus, considering the impure air of a room simply as matter, subject solely to the laws of force, moving only as *moved*, we have at our command, and through these structures use, as forces, *wind and heat*, acting efficiently, separately or concurrently, effecting the desired change of air.

We thus provide for the efficient and quiet ventilation of any building, at all times, unless in the extremely rare but theoretically possible case of the failure of both forces.

But if, by respiration and radiation the temperature of the air is not increased, and if, at the same time, there is no appreciable movement of the external air, it is perfectly safe, and may add to comfort, to open all doors and windows.

Providing, as we do, for all cases in which it is desirable to close them because of the discomfort due to cold air or to currents; securing, as we do, at all such times, results closely bordering on perfection; we need not be too solicitous in regard to a possibl

conjuncture of conditions which may not exist during a single hour in a year, and for which provision can be made *only*, EVEN IF, by the use of a "mechanical power," already at your command.

Our ventilators standing on the roof, so low as not to be conspicuous from the ground, should be sufficiently large and numerous to correspond to the wants of the largest audience; only a portion of them being in use when the audience is small.

The tubes or boxes in the attic would need to be very large and complicated, extending over the entire galleries on all sides of the halls.

The ceiling over these galleries is very open, affording all or nearly all of the needed space.

In the ceiling of the Senate chamber no change would be needed, and in that of the House only an enlargement of the openings at about 200 points, between the brackets, next to the walls on all sides of the hall—a change not noticed unless on close inspection.

All of these *pores* in the ceiling would be used for the actual passage of the incoming and outgoing air.

They are admirably arranged for its proper distribution, in streams mild as the gentlest shower, the rising vapor, or the falling snow.

The halls might almost be said to breathe, taking in the good and expelling the bad air. If all breathe in unison, the halls as fast as the audience, as they may, nothing better can be required. Let the carbonic acid, observant of fundamental law, float into the outer air, as it will, all authorities and all theories "to the contrary notwithstanding," and we need have no fear that vegetation will fail to perform its work, and make the needful restoration.

From this "carbonic acid question," on which no darkness needs to rest, it would afford me pleasure, if time allowed, to brush the mists and myths with which false teaching has surrounded it.

Orally, I often discuss it in full, and shall be pleased *thus* to give to the committee, if they desire, the facts and the law of the case.

Not merely these large halls, but their surroundings also can be vastly improved.

Over each stairway, besides the glass, is a very extensive porous ceiling.

All of this open space I would convert into immense respirators, our large, complex, and very angular boxes covering the whole, and connecting it with *giant* ventilators standing on the roof over the passages at the head of the stairs.

Through our ventilators and boxes thus arranged, injection *and* ejection will be effectually accomplished, securing throughout the stairways and connecting passages a state of freshness hitherto unknown, and not attainable, unless at enormous cost, by any other known plan.

All the rooms opening into these passages, especially those above the first story, will be improved in condition; and most or all of those occupied by a few persons may be sufficiently ventilated by the frequent opening of doors, allowing direct communication with a reservoir of fresh and constantly changing air.

There can be no doubt as to the operation and results above indicated, as I have at least a score of successful similar cases.

The effect, I have no doubt, will be appreciable even below the level of the floor of the legislative halls, but in all the space above that level it cannot fail to be most marked.

These ventilators should be so large that if 3,000 persons should occupy the stairways and passages in each wing, with all doors and windows closed, there would be no suffering for want of pure air.

This arrangement alone would be of vast benefit to the occupants of the legislative halls, especially when the audience is large, as all the doors from the halls would be likely to be then open.

Such, gentlemen, is the general plan which I shall offer to apply to the wings of the Capitol.

Its universal success, wherever properly applied, is an index of what we may expect in the future.

In the House, a few weeks since, reference was made to the discomfort due to heat from the burning of gas above the ceiling.

A plan for securing almost complete protection from that annoyance can be easily applied.

Very respectfully,

LUTHER ROBINSON,
Agent of U. S. Ventilation Co., of Boston.

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46 CONGRESS STREET, BOSTON, *May* 5, 1870.

DEAR SIR: As your committee have the money appropriated for experimenting, would not it be well to use a part of it in the actual ventilation of some room, so that results

can be seen and appreciated? The court room in which Surratt was tried, the common council room, all school rooms, &c., greatly need ventilation. That court room I could ventilate probably for $500 or less, so that two hundred men could not "smoke it out," or make much bacon there, and all would be right for permanent use.

If your committee would like to let me use up a part of the money I think I can show them highly satisfactory results.

I hardly had time to say to you that the annoyance mentioned in the discussion, of excessive heat from the gas, can be vastly diminished at small cost, and within a few days. I have no time now to explain details.

Yours, truly,

L. ROBINSON.

Hon. T. A. JENCKES.

WASHINGTON, *June* 23, 1870.

To the congressional Committee on Ventilation:

GENTLEMEN: I offer to apply to the southern wing of the Capitol the system of ventilation already described, using for the stairways two nicely constructed ventilators of wood, not less than 6 feet square, and for the hall of the House two of the same size and style; also six of galvanized iron, 3 feet square, all well made, painted, and strongly fastened to the roof. The interior tubes or boxes connected with them to extend over the ceiling of the entire galleries and the iron ceiling over each stairway, but not intercepting the light over the stairs. To protect the boxes in the attic from the effects of heat, their exterior to be lathed and plastered. Proper valves to be arranged with cords extending to some convenient point, as the stairway leading to the attic. All mechanical work to be properly done, to the satisfaction of the committee, or such agent as they may appoint. The amount of ventilation thus proposed for the hall, independent of the indirect effects from ventilating the stairways and passages, being more than three times as great as I have ever applied for two thousand persons, cannot fail to be abundant for any audience. Indeed, under ordinary circumstances only a small portion of the entire efficiency would need to be used.

I have had much opportunity to study the effect of heat as transmitted through roofs, windows, walls, &c., and in several instances have caused valuable remedies to be applied.

When the lights are burning in the attic the temperature, I am told, is from 180° to 200°. If the ceiling were tight and covered with water at nearly a boiling temperature there would be no doubt as to the communication of an uncomfortable heat to the air below. From the great heat of the air in the attic, the glass and iron of the ceiling afford no sufficient protection. The obvious remedies are to ventilate the attic more efficiently, and to protect the ceiling from contact with hot air by covering the whole with good non-conductors.

If our plan of ventilation should be applied, as proposed, all of the ceiling over the galleries would be abundantly protected. The other portion of the ceiling, except the glass, should be covered with some non-conductor, as shavings from a planing-mill, and a tight floor, on proper frame work, laid over the whole; or, above this part of the ceiling there might be two floors, with intervening closed air spaces, affording almost complete protection from the heat above this portion of the ceiling.

Over the glass I would propose to place additional sashes fitted with two panes of white glass in each panel. Make all tight around the old sashes, and there would be between the heads of members and the hot air above three plates of glass and two intervening masses of confined air, and the annoyance from this source will be reduced to a minimum.

My proposal will include—

1. The ventilation of the stairways and passages, as described.
2. The direct ventilation of the Representatives' hall, as described.
3. The more efficient ventilation of the attic, as I may deem expedient.
4. The better protection of members from heat from the gas, on the plan above described.

The total expense of all these improvements I estimate at $30,000.

I am ready to execute the whole in proper style for the sum named, one-half to be paid on completion of the mechanical work described prior to the middle of November next, to the satisfaction of the committee or of their agent, if one shall be appointed; and the other half after a reasonable trial of the system and the securing of satisfactory results.

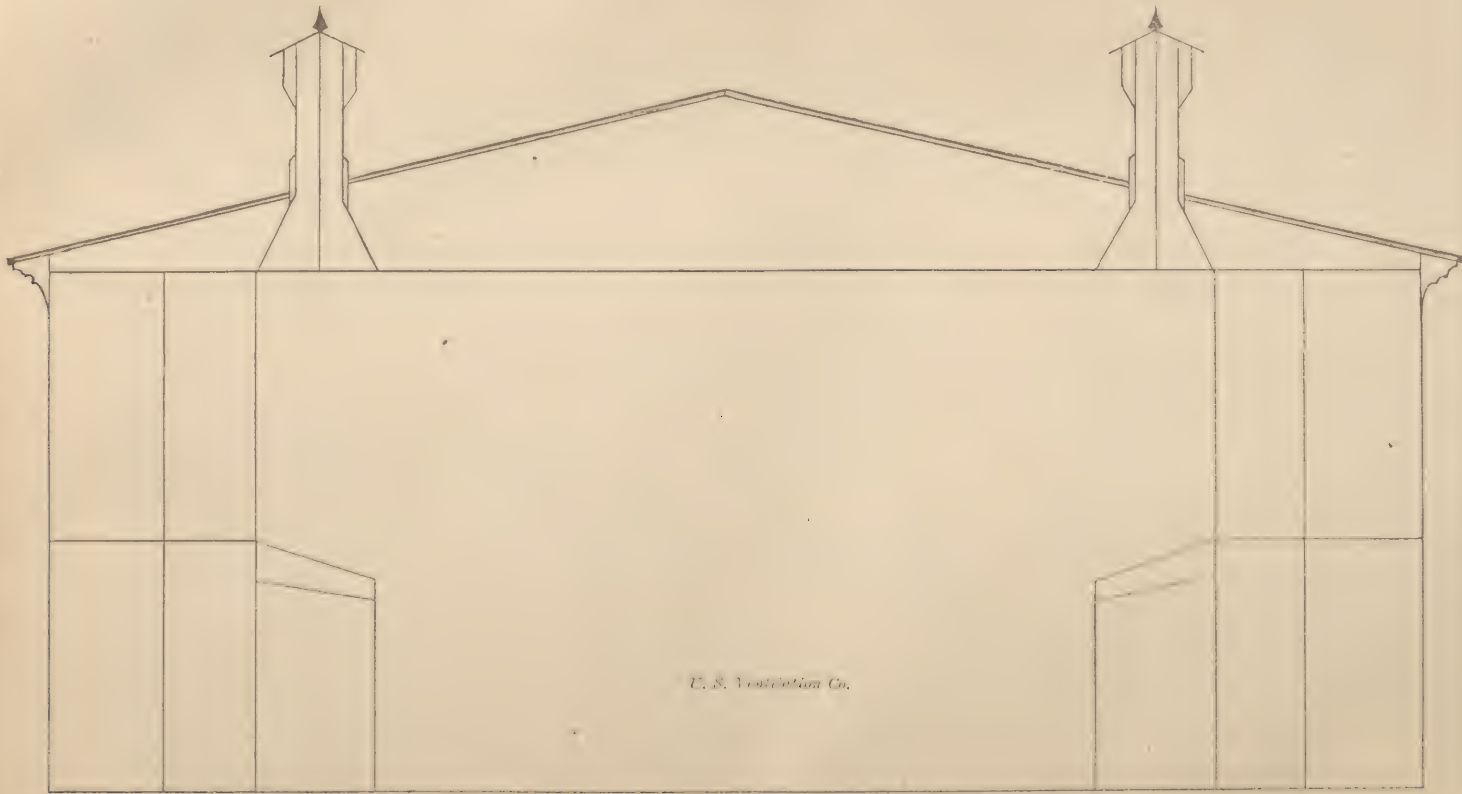
The Senate chamber, being smaller, would require arrangements less extensive. This wing I could ventilate satisfactorily and furnish similar protection to the ceiling for $20,000.

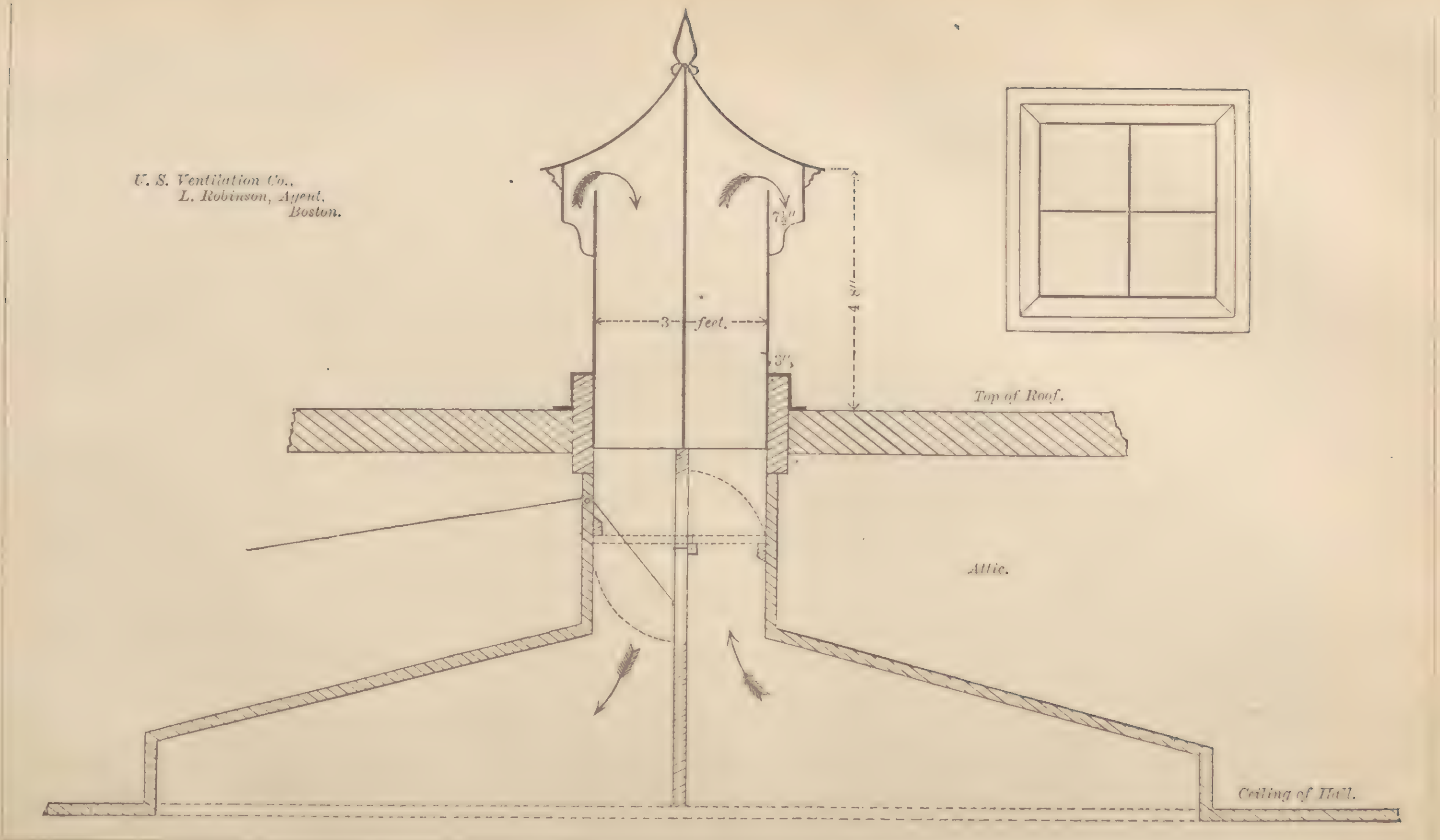
Very respectfully,

LUTHER ROBINSON,
For himself and the United States Ventilation Company of Boston.

LUTHER ROBINSON'S PLAN FOR VENTILATING THE WINGS OF THE UNITED STATES CAPITOL.

Sketch showing a cross-section of the Representatives' Hall, and one view of ventilators on the roof spreading across the galleries.




U. S. Ventilation Co.,
L. Robinson, Agent,
Boston.
3 feet.
4 8"
Top of Roof.
Attic.
Ceiling of Hall.

BOSTON, *July* 6, 1870.

SIR: I propose to apply to the south wing of the Capitol the system of ventilation described in my printed pamphlet, recently sent to you, substantially as follows:

1. At proper points near the glass over each stairway apply a ventilator 6 feet square, (or two of 4 feet square,) the boxes in the attic being so arranged as to use all of the open space over the stairways as mouths of the ventilating boxes. The boxes above said space to be so constructed as not to obstruct the light, the divisional planes being all vertical, and the glass of the roof forming the upper surface.

2. For direct ventilation of the Representatives' hall, at proper points on the roof apply eight ventilators, each 4 feet square, the boxes within the attic being so spread and arranged as to cover the entire galleries, using as mouths all of the open surface of the ceiling.

The openings between the brackets, next to the walls, I should wish to enlarge as much as practicable without disturbing the molding.

The boxes within the attics to be of galvanized iron, properly seamed, or riveted and soldered, all being strengthened and kept in place by such iron rods or frame-work as may be needful. All work to be well done.

Valves on iron axles to be of plate-iron of proper thickness, and cords for working them carried to some convenient point, as the stairway leading to the attic.

All the ventilators on the roof having for strength and stability a frame-work or foundation of wood, to be entirely and nicely covered externally with copper and lined on the interior with galvanized iron, so as to be entirely fire-proof.

Two of these ventilators would be abundant for any audience that I have seen in the hall, and the whole proposed is sufficient, under ordinary circumstances, for at least six thousand persons.

I am ready to contract to have the whole completed on or before November 20, in accordance with the spirit of the printed "plan" and of what is above written, in style and manner satisfactory to the committee after examination early in December, for the sum of $10,000, one-half to be paid on examination and approval of the mechanical work by the committee as above, and the other half on their approval of the results secured during the month of December.

Very respectfully,

LUTHER ROBINSON,
Agent United States Ventilation Company of Boston.

Hon. THOMAS A. JENCKES,
Chairman Committee on Ventilation.

P. S.—Within a few days I have seen an illustration of the benefits of this system as used in very hot weather—the air of a large occupied room being kept fresh and comfortable at 80°, while in similar rooms the temperature was 98°. Sufficient ventilation was received, excessive ventilation avoided, and every window was closed.

I am sure that the ventilation of this hall in hot weather can be so managed that the temperature shall be from 12° to 20° lower than if doors and windows are left open, as during the last month.

Respectfully,

L. R.

BOSTON, *January* 18, 1871.

DEAR SIR: I inclose a sketch showing a cross-section of the Representatives' hall, and one view of ventilators on the roof spreading across the galleries. The sketch formerly sent shows a ventilator, with box in the attic, spreading lengthwise. A series of them would cover the entire galleries. The proportions may not be accurate, but I am sure there must be abundant space to work in the attic.

The fans would never be needed for *ventilation* if our plans are used, although possibly in very warm weather currents of air from them, cooled by ice, or water, might give increased comfort.

We have found no difficulty whatever in the use of our plans in rooms warmed by hot air, where heat from furnaces or steam-pipes is the moving power.

Whether air is driven in by heat alone, or by fans, or by both, the principle is the same, and if we make our ventilators and the openings in the ceiling large enough, I cannot doubt that the results would be entirely satisfactory. As a matter of choice I should prefer that the fans should not be used at any time.

With the vast amount of steam-pipe used I think there can be no difficulty in supplying an abundance of air for warming, even without the aid of fans. If used at all, I should prefer to have them used only before the sessions, or at a *low speed* during the sessions.

The numerous openings in the ceiling are abundant for any ordinary audience; but the ventilating area can be increased by about 50 square feet if we remove the finely

perforated iron now between the brackets, on all sides of the hall; or still more by removing that and the surrounding moldings, gaining thus, perhaps, 160 or 180 square feet. In either case, these spaces should be covered by very open ornamental work. The space cannot fail to be abundant, even if the (interfering) fans *are* used, at full speed.

The true way is, to abandon the idea of using fans with any view to *aid in ventilation*, for which purpose they are surely unnecessary. If ever used, it should be to supply cooled air in very hot weather, or to aid a little, if needful, in supplying air for warming the halls in advance of occupancy.

Excuse unavoidable delay in making these promised suggestions.

Very respectfully, yours,

LUTHER ROBINSON,
Agent United States Ventilation Company.

Hon. THOMAS A. JENCKES.

VENTILATION OF THE HALL OF THE HOUSE OF REPRESENTATIVES.

JUNE 20, 1868.

Mr. Covode, from the Committee on Public Buildings and Grounds, made the following report:

The Committee on Public Buildings and Grounds, to whom was referred the resolution—

"Whereas the confined and poisonous air of the hall and corridors of the Representatives' wing of the Capitol has caused much sickness and even several deaths among the members of the House, and under present arrangements must continue to remain in a poisonous condition: Resolved, That the Committee on Public Buildings and Grounds be directed to examine at once and report to this House by what means a sufficient supply of pure air may be obtained for said hall, and that said committee be empowered to use the present means of ventilation to the best advantage for the present; and that they report by bill or otherwise."—make the following report:

That they have given much attention to the subject. That after examining the several reports that have heretofore been made regarding the ventilation of the hall, they find the views of the most eminent men widely differing. First, as to any necessity for further ventilation; and second, should there be any need of improvement in this respect, how it could best be secured. It seemed to your committee that much of this wide difference of opinion was due to the entire want of positive facts, such as: First. How much fresh air does really enter the hall? Second. How much of the air flowing into the hall comes from the corridors, galleries, smoking-rooms, &c.? Third. Is there a fair and even distribution of the fresh air (if there is any) over the entire floor of the House, or does it all flow through one portion and leave the other portion stagnant and foul?

With the hope of eliciting some more definite information in regard to these points, your committee determined to call in the assistance of some professional men who had devoted much time to this subject. They first called upon General Herman Haupt, an engineer distinguished not less for his scientific attainments than for sound judgment and long experience.

General Haupt graduated at West Point in 1835; he has been favorably known to the chairman of the committee for more than twenty years, as chief engineer and general superintendent of the Pennsylvania Railroad. For several years he was professor of mathematics, civil engineering, and architecture in Pennsylvania College.

The systems of ventilation as applicable to mines and tunnels also received at his hands a thorough experimental investigation, and results of the highest practical importance were elicited.

For these reasons the committee have considered the opinions of General Haupt as eminently worthy of confidence, even in opposition to the distinguished names that have been appended to previous reports.

The report of General Haupt is appended to this report.

The committee also called on Mr. Lewis W. Leeds, a gentleman who has devoted his attention exclusively to the subject of ventilation for many years past; was consulting engineer of ventilation for the Quartermaster General and Surgeon General during the war, in which service he gave the plans and directions for the ventilation of most of the Government hospitals, the practical results of which have been spoken of in the highest terms by all the medical men and other officers acquainted with the operations thereof.

The system of ventilation adopted for these hospitals also received the highest commendation from the committee on sanitary arrangements at the late Paris Exposition.

Mr. Leeds is at present consulting engineer of the Treasury Department, and has arranged the ventilation for the various new buildings under the charge of that Department. His report, with a number of diagrams, giving a record of a large number of experiments, and giving also a summary of the results as indicated by those experiments, is also appended to this report.

Mr. Leeds's report gives the record of twenty-six experiments, tried on the 5th instant, for the purpose of determining the direction of the perpendicular currents in the loft over the hall of Representatives. These show that the air from the loft is falling down into the hall all around the northeast and south sides of the room: it rises in the west.

Twelve different experiments show the temperature on the afternoon of the 5th to range from 44° to 48° around the exterior, and only 56° on the glass ceiling immediately over the center of the room. At 9 o'clock on the morning of the 7th, the thermometer was 38° in the loft.

Fifteen experiments tried on the morning of the 6th show these cold currents from the loft to sweep down on the outside of the galleries, carrying with them all the air contaminated by the crowds in these galleries, and pouring it over into the floor of the House: this occurs on the northeast and south sides of the House, rising on the west.

There was a strong current found to be setting *in* to the House from every external door both on the floor and in the galleries. Thus it will be seen that instead of the hall of Representatives being overflowed with fresh external air, and, as we have been so often told, with 40,000 or 60,000 cubic feet per minute, the truth is, the floor of the House, where the members sit, receives the washings from the foul corridors, galleries, loft, &c., and is really the foulest place in the whole building.

There is a very small amount of air, indeed, coming in through the registers on the floor of the House; but this, by some, may be considered an advantage rather than otherwise, as many of them are so choked up with tobacco spittle and sweepings of the floor as to render the air rising from them very disagreeable.

Your committee have tried a number of these experiments with Mr. Leeds and find them substantially correct.

It is very evident from these experiments that the original intention of the designers must have been so mutilated by subsequent alteration as to entirely defeat the object desired to be gained, and that there is now a necessity for some decided change.

General Haupt enters into an elaborate argument to show that the carbonic acid and other impurities from the lungs and skin fall to the floor, and consequently provision should be made for the removal of the foul air from that point. He proposes leaving the entrance for the heated air at the floors as at present arranged.

Mr. Leeds quite agrees with General Haupt that the carbonic acid from the lungs falls to the floor in a still room with a temperature of 70°, and that an excess would be found there, especially where all the air enters warmer than the required temperature of the room. He thinks there should be openings for the escape of the foul air from numerous points over the floor.

Mr. Leeds says, however, that the whole system of heating *exclusively* by circulating warmed air is wrong, and that no building can ever be made comfortable and satisfactory in that way; that where all the air is heated hotter than is required for breathing, it produces languor and debility similar to what is felt of a hot, close summer day. He says that it is absolutely necessary that there should be a considerable amount of direct radiation, and proposes that there should be several good old-fashioned wood fires, and perhaps some steam radiators placed in some portions of the room; or, what would answer equally well, to have the sides of the walls heated to about the temperature of our bodies, or a little warmer, so as to be radiating heat to us instead of robbing us of it.

Mr. Clark, the present Architect, quite agrees in this opinion, but thinks it would be better to have the fires in the cloak-rooms. He also says he thinks the present floor should be taken up, and either the whole space under the floor be used as a general hot-air chamber, or that there should be a different adjustment of the flues, as since the completion of the building one-half of the registers have been removed by parties not connected with or familiar with the original construction of the building; and he thinks the original construction of the flues has been materially interfered with, as it is now difficult to heat the side farthest from the entrance of the warmer air to the same height by several degrees as that nearest the entrance thereof.

It must be very evident to every one, from the results given of the experiments tried, that when the gas is lighted much of the foul air and products of combustion must descend into the hall. This ought to be prevented.

Your committee believe, as expressed by Mr. Leeds, that it is essential that the direct rays of the sun should shine into every occupied room to preserve it in a pure and wholesome condition. And they believe it quite possible that some plan might be devised by which this desirable object could be accomplished at small expense and without materially changing the present construction of the building.

Your committee would recommend that a competent person should be employed to

make such further examinations and experiments as may be necessary to determine the conditions of the ventilation under the various changes of wind and temperature, and that he make a report, with such plans as may be necessary for illustrating these suggestions as to the best means of improving the ventilation and the heating and lighting.

To the Hon. John Covode, Chairman of Committee on Ventilation :

An examination of the ventilation and heating of the hall of Representatives at the Capitol has fully convinced me that very serious defects do actually exist in the present systems.

But I find, after a careful examination of the elaborate reports of Professor Henry, Dr. Wetherill, Thomas U. Walter, and others, that I am obliged to differ with these gentlemen as to the best means of ventilating this building.

In thus differing in opinion with such distinguished gentlemen, I shall feel it my duty to express fully the grounds upon which I base that opinion.

FUNDAMENTAL PRINCIPLES OF VENTILATION.

The plans proposed for the ventilation of the hall are based on two simple propositions:

1. Heated air is relatively lighter than colder air, and will continue to ascend and the cold air to descend so long as they are free to move.

2. More or less than a given quantity of air, practically considered, cannot occupy an apartment, and air cannot be introduced unless an equal quantity be withdrawn, or withdrawn unless an equal quantity be introduced.

These two simple and self-evident propositions will explain nearly all the phenomena observable in ventilation.

PHENOMENA OF VENTILATION.

If heated air is introduced into an apartment containing air at a lower temperature, through registers at the floors, it rises rapidly to the ceiling; and if there are openings at the ceiling it escapes without, except in a very slight degree, mixing with the air in the apartment. The air that passes off in this manner is absolutely lost and the heat imparted to it wasted. It does not remove the vitiated air contained in the lower part of the apartment; it does not form with it a homogeneous mixture, and does not communicate to it more than a small portion of its heat. But if, instead of the escape openings at the ceiling, they are placed at the floor, the phenomena observed will be widely different. The heated air will, as before, rise to the ceiling, but instead of escaping will press the colder air downward toward the exit ducts and fill the apartment with pure, warm air; the air vitiated by breathing will at once sink below the level of the mouth and in a few seconds will be carried off, no accumulation of foul air being possible. In these few words the whole theory of ventilation is in a general way presented: it only remains to make an application to the case under consideration.

QUANTITY OF AIR REQUIRED.

In the able report of Dr. Wetherill (Ex. Doc. No. 100, 36th Congress) various opinions are given as to the amount of fresh air necessary to render the products of transpiration and respiration innocuous. These estimates, made by distinguished observers, vary from 2 to 50 cubic feet per man per minute.

These estimates are generally made upon the hypothesis that the fresh air introduced into an apartment mixes uniformly and homogeneously with the vitiated air and dilutes it to an extent sufficient to render it innocuous; but if, instead of mixing with the air of the apartment, *the warm, pure air* should rise to the ceiling and escape, all conclusions based on the hypothesis of homogeneous mixture would be fallacious; and this fallacy, it appears to your committee, pervades the whole of the very able scientific reports that have been heretofore submitted.

The House of Representatives has a capacity of 465,372 cubic feet and is supplied with 60,000 cubic feet of fresh air per minute, which Dr. Wetherill assumes will change the whole air every seven minutes and furnish to each of a thousand persons 60 cubic feet per minute.

If the whole air were changed every seven minutes, or even once in an hour, the ventilation would be ample, whereas it is notoriously defective. It is obvious, therefore, that nearly all of the 60,000 cubic feet per minute must on the present system escape without performing its intended office in purifying the air.

If air that has once been respired could be immediately removed without being a second time taken into the lungs, it is obvious that so far as respiration is concerned

no more air need be introduced into an apartment in a given time than can be breathed. This amount is easily calculated.

At a temperature of from 65° to 70° Fahrenheit the following average results are given by Dr. Wetherill, for the respiration of an adult:

Number of respirations per minute	20
Cubic inches of air inhaled at each respiration	20
Cubic inches per minute	400

The carbonic acid exhaled is stated to be 15 cubic inches per minute, and the surrounding air vitiated is $2\frac{1}{2}$ cubic feet per minute.

Four hundred cubic inches is less than one-fourth of a cubic foot, and this is all that can be taken into the lungs per minute. It would seem reasonable to suppose that if this small quantity could be removed at once, so that no portion of it could be breathed a second time, no greater amount of air for respiration could be required. Certainly it would seem that the removal of the $2\frac{1}{2}$ cubic feet vitiated by respiration would be an ample allowance. What judgment, then, should be pronounced upon the present system, which with 60 cubic feet per man per minute fails to remove the vitiated air?

The quantity of air introduced is twenty times as great as the quantity that could be vitiated by respiration, provided there was a homogeneous mixture. The facts which are daily observed prove that such homogeneous mixture does not exist under the present system.

If nineteen-twentieths of the heated air which enters the apartment escapes without being utilized, it follows that nearly all the fuel consumed in heating it has been wasted.

POSITION OCCUPIED BY VITIATED AIR.

In the process of respiration 15 cubic inches of carbonic acid per man per minute are ejected from the lungs. This gas in course of time would diffuse itself throughout the apartment, but it is well known that its density is so great that it can be poured from one vessel into another, or if poured into an inclined trough it will flow downward, extinguishing successively a row of lights. The specific gravity of this gas is 1.52, or 52 per cent. heavier than air. Its tendency would therefore be when exhaled to sink below the level of the mouth, and occupy the lower portions of an apartment near the floor; but it has been supposed that the elevated temperature at which it is projected from the lungs causes this gas to rise and escape at the roof. The fallacy of such an opinion can be readily proved.

Even if the temperature at which carbonic acid escapes from the lungs should be so elevated as to render it momentarily specifically lighter than the surrounding air, it would soon part with the excess of heat and then seek the level due to its superior density; but, in fact, under the condition of things which actually exists, there is only about 20° difference in temperature between the air when first expelled from the lungs and that of the apartment. As air increases in volume $\frac{1}{480}$ of its bulk for each degree of Fahrenheit. The effect of increasing the temperature 20° would be to reduce the specific gravity less than 10 per cent., and the carbonic acid upon leaving the lungs would still be 40 per cent. heavier than the air of the apartment. It would seem impossible for this dense gas to rise to the ceiling and escape at that level without a violation of the laws of pneumatics, and yet the projectors of the present system of ventilation made no provision whatever for its escape at the level of the floor, at which level alone it is possible effectually to remove it. Mr. Clark, the present Architect, seems to have appreciated the necessity of doing something to remove the carbonic acid at the level of the floor, and he provided an 8-inch tin pipe connecting with one of the registers, but an exit duct fifty times the area of the present openings in the register would not be sufficient, and the inlet and exit ducts should allow of the passage of nearly equal volumes.

DEFECTS OF PRESENT SYSTEM.

The defects of the present system of ventilation are apparent from the preceding considerations. Although 60,000 cubic feet of heated air per minute are forced into the hall through registers in the floor, nearly the whole volume rises rapidly to the ceiling and escapes through openings provided for it without carrying with it the carbonic acid and other impurities, and this evil is greatly aggravated by the fact that not only the air vitiated by the members, but also that from the galleries, often crowded to excess, seeks the lowest level in the hall, to the great injury and discomfort of all whose seats are near the floor.

REMEDY FOR EVILS.

The remedy is simple; it consists in an application of the principles contained in the two propositions which were enunciated at the commencement of this report: Close

the openings at the ceiling, and make others of area equal to the inlet registers at the floor and around the galleries. The exit ducts should communicate with flues in which a current may be maintained by means now in use; but it would, in my opinion, be greatly intensified by throwing the exhaust steam from the engine or boilers in intermittent jets into this flue, instead of allowing it, as at present, to escape without being utilized.

PHENOMENA OF VENTILATION UNDER THE PROPOSED SYSTEM.

The heated air entering the hall through the registers would rise at once to the ceiling; unable to escape, it would accumulate and press downward the air previously in the apartment, until in seven minutes the whole of the air would be changed, the dense and foul air being carried off at the level toward which it naturally flows, and at which alone it can be removed. This operation is greatly facilitated by the large exit ducts connected with the flues. It will be perceived that, under this system, the tendency of the pure air is first upward, in currents, and then slowly downward. The exhaled gases sink at once below the level of the mouth, reach the floor, and are carried off. From a height of four feet above the floor they would descend and be removed in less than a minute, and it is probable that less than one-fourth of the fuel now consumed would maintain a proper temperature, as a much larger portion would be utilized.

The vitiated air from the galleries should be drawn off by flues inside the balustrade, and at the lowest level. No fears need be entertained that any considerable portion of foul air would be projected over the balustrade and into the body of the hall. All that did enter the hall in this way would be drawn off through exit openings on a level with the floor below the galleries, and there should also be a very large exit opening in the center at the lowest level of the floor in front of the Speaker's desk. As the gallery is supported by an 18-inch brick wall, there is no difficulty in making these alterations, and the best manner of doing it can be readily determined by the intelligent Architect of the Capitol. The committee have not entered upon the details; the principles involved seemed to them to be much more worthy of their careful consideration.

MOISTURE.

I would suggest, as the most simple and practical mode of moistening the air in winter, that a jet of steam from the exhaust-pipe of the engine be thrown among the heating coils, the amount of which could be regulated at pleasure, and would help to economize fuel. I also concur with Mr. Clark, the Architect of the Capitol, in the opinion that, for summer ventilation, the air should be cooled and moistened by being drawn through the spray of fountains and carried over the surface of water basins at the bottom of the inlet ducts.

I also unite with Mr. Clark in recommending, in strong terms, the importance of having all the arrangements for heating and ventilation under the charge of the engineer or some other responsible and intelligent person, who, by means of suitable thermometers and hygrometers, should ascertain the temperature and the hygrometric condition of the air, and maintain both at such uniform standard as may be prescribed.

EFFECTS OF COMBUSTION OF GAS.

It is asserted in Dr. Wetherill's report that each flame consumes as much oxygen and gives out as much carbonic acid as five human beings. This is an additional and strong argument in favor of the proposed change in the mode of ventilation. As the gas jets above the ceiling are separated from the hall by intervening glass, the carbonic acid can be effectually prevented from entering the hall by closing the openings at the ceiling.

OBJECTIONS CONSIDERED.

It has been asserted that downward ventilation has been tried, and has not proved successful. No reliance can be placed upon a statement of this kind unless the circumstances and conditions under which the trial was made could be ascertained. Success or failure often depends on the manner of doing an act. So far as the report of Dr. Wetherill gives facts, the evidence is in favor of downward ventilation. In the observations of General Morin, page 65, it is stated that a ventilation of 148 cubic feet per man per minute, *principally downward*, left no perceptible odor in a lecture-room, while the *upward ventilation* of the halls of Congress, with 69 cubic feet per minute, is notoriously defective.

On page 69 is found a paragraph on "the direction the products of respiration take after leaving the body," in which it is attempted to prove that the direction is upward. The evidence in support of this position is that when the author of the report smoked a pipe at the Smithsonian Institute the smoke ascended. But the objection to this experiment is that tobacco smoke is not one of the ordinary products of respiration, certainly not in the halls of Congress. The experiment does not prove that the gray smoke which was seen to rise was carbonic acid; the experimenter does not state in

what direction were the ventilating currents in the apartment, or how produced; and there was nothing in the experiment to prove that, with a gentle downward ventilation, the smoke would not have moved downward, instead of upward. In fact, it proved nothing at all in reference to the direction of the products of respiration.

In contradistinction to such crude experiments is the fact that a system of downward ventilation has quite recently been introduced into the Pennsylvania Hospital, at Philadelphia, with perfect success. It was also very extensively introduced into the Government hospitals during our late war, and proved highly satisfactory. The open fireplace, too, is a very familiar illustration of the value and success of lower ventilation.

In conclusion, I would strongly urge the adoption of this system of ventilation, and recommend that the Architect be directed to prepare plans at once, suggesting the most convenient method of executing the work, to be submitted to Congress.

Truly yours,

HERMAN HAUPT.

To the Hon. John Covode, Chairman of Committee on Ventilation of the House of Representatives:

I have read with care and much interest the report of General Herman Haupt on the ventilation of the House of Representatives.

I quite agree with him in his conclusions both as to theory and the necessity for putting in practice a system of exhaust for ventilation from the floor of the House.

Very extensive practice and close observation for many years past have fully convinced me that the human breath, which is the great source of contamination, in an occupied room tends first toward the floor in a still room of 70°, and that there is a probability in a closely occupied room that there will be quite an excess in the accumulation there.

This applies especially to rooms warmed exclusively by hot air.

The contrary opinion—that is, the assumption that the breath and impurities exhaled from the body rise to the ceiling and accumulate there, was advocated strongly in the ventilation of the English houses of Parliament. And as some two or three millions of dollars were spent, I believe, in endeavoring to heat and ventilate that building comfortably, and as the proceedings in regard thereto were spread over the world to an extent probably one hundred times greater than any previous publication or action in regard to the ventilation of any public building, that theory of ventilation became strongly impressed upon the public mind as being the correct one.

I consider that idea erroneous; hence all theories of ventilation based upon it are consequently wrong.

But we must notice this applies to rooms warmed exclusively by heated air. We must not fall into the error the little boy did who, receiving a good thick overcoat on a right cold day, found it exceedingly comfortable, and being so thoroughly convinced in his own mind of its great value, insisted on wearing it warm days too.

In the majority of our rooms the excess of the air entering (which we must of course assume to be the pure air) does not enter warmer than the contained air one-half of the time, and probably not more than one-quarter of the time.

It ought never so to enter. This whole theory of warming rooms exclusively by hot air is entirely wrong, and the discomfort experienced in the present halls of Congress is probably as much owing to the want of some direct radiation in the rooms as to any excess of carbonic acid present.

I have given much attention to this subject within the last year, and my observations fully confirm the opinion that no building in which all the air for breathing is heated hotter than the required temperature of the room (no matter how the air is warmed, whether by steam, hot water, or otherwise) can ever be made entirely satisfactory.

When the air breathed is nearly of the same temperature of the body it loses its invigorating influence; it produces languor and debility.

We all know the exhilarating effect of a cool bracing air of a clear, bright sunshiny day. The direct radiation from the sun is very powerful. A thermometer protected from the influence of the wind and laid in the sun of a clear, bright day in winter, with the air below the freezing point, will rise to near 90°. This is the condition most favorable to active exercise, bodily or mentally, and must be approached in our artificial arrangements before real comfort can be secured.

Any member can easily satisfy himself upon this point by a few days' observation of the effect produced upon his own person while in the halls of Congress, which are warmed exclusively by heated air; and comparing that with the effect produced in a room with an open fire, (if he should be so unfortunate as to be in a room heated by hot air at home, as well as at the Capitol, I pity him,) he will soon find that five hours' labor, especially mental, will be more exhausting in the former than seven hours in the latter room, all other conditions being equal.

He will also soon notice that in the room with the open fire his head will be clear and his thoughts flow freely, while in the room heated by hot air his head will be full and oppressed, his thoughts will become confused and clouded, and to perform a certain large amount of work becomes very fatiguing both to body and mind.

I consider it absolutely essential, therefore, that some modification should be made in the manner of heating the halls of Congress.

Care should be taken, however, not to rush to the other extreme and get too much direct radiation.

A room heated exclusively in that manner, with all the fresh air entering of the temperature of the external atmosphere, causes cold unpleasant draughts which can and ought to be avoided.

The decided preference given of late years to heating exclusively by direct radiation, over heating by circulating warmed air, shows that the former with all its objections is preferable to the latter.

The combination of the two, however, produces the most satisfactory results.

The best possible manner of applying these principles would require considerable thought and a careful examination of the building.

The open fire is one of the best sources of radiant heat; it more nearly imitates that from the sun than any other in common use.

Some persons might object to having open fires in the hall of Representatives, but I don't know why it should be so objectionable. Direct radiation from steam-pipes would be much less trouble, and would be preferred, no doubt, on many accounts, for producing the greater part of the radiant heat.

Another very serious objection to heating exclusively by warmed air is that precisely the same temperature is scarcely agreeable to two persons in a hundred, and even the same person wants a constantly varying temperature according to the ever-changing conditions of his system.

It is of course exceedingly difficult, and perhaps entirely impossible, to fully meet all these varying wants, but it would not be difficult to come much nearer to it than at present.

It might be possible for steam-pipes to be arranged under the floor and covered by soapstone foot-stools, so that each member could regulate the heat at his own desk at pleasure; but this might not be of sufficient importance to make it advisable to have it put in practice.

Now when the manner of heating is changed it may affect the arrangements for ventilation. One thing, however—the importance in regard to the location of the inlets and outlets of the circulating air diminishes as the proportion of the heat derived from direct radiation increases.

I believe it would be at all times and under all circumstances very desirable to have a large amount of the air drawn from the floor, as nearly as possible from under or near each member's seat, and also from under the seats of all the benches in the galleries. But to know how and when and how much to draw from the ceiling would be a much more difficult question to decide.

The openings at or near the ceiling require to be closed and opened according to the varying conditions of the room, and it can only be ascertained how they can be best regulated by experience.

That there should be such openings we all know from our every-day experience of the necessity for opening doors or lowering *external* windows, (where we are so favored as to have that luxury), to relieve the upper part of the room when it gets too warm.

I think the present arrangements for introducing the air very objectionable. If there were a considerable amount of heat furnished by direct radiation, so that the inflowing air could be several degrees below the required temperature of the room, it would have a delightful refreshing effect to have it fall in gentle currents from the ceiling, and this would cause the least possible disturbance of the atmosphere, which is very essential in producing the best acoustic effect.

We all know if our feet and backs are kept perfectly warm and comfortable we are all right. We can then bear a large amount of cool refreshing air in our faces and on our heads.

To successfully heat and ventilate a large complicated building it is of primary importance that you should have a thoroughly comprehensive plan that shall include, not only the whole building, but all its surroundings.

Heat applied within any building causes movements of the air with more or less force, according to the difference of temperature of the external and internal atmosphere. The external wind is a source of considerable power. These two forces, if properly applied, are sufficient to ventilate an ordinary building nearly every day in the year; there may be a few days, however, when the external air is almost stagnant and it is too warm to have heat in the house; it then becomes necessary to resort to some artificial power for the movement of the air. This can be done by the application of mechanical means, as at the halls of Congress at present, or by the more simple and direct application of heat to exhaust-flues.

But the important matter is in the application of this power to make it conform to and coöperate with the natural forces and merely assist their action, or otherwise make it of sufficient power to entirely overcome all these natural forces.

If much care is not exercised in the adjustment of these forces, one will just counterbalance the other, and stagnation is the result. This, I think, is frequently the case in the Capitol building.

I have never made any examination to ascertain the fact, but it seems to me probable that the air entering the hall becomes foul in passing through it and rises into the space under the roof and there becomes cool, and much of it becoming mixed with the air from the burning gas, tumbles back into the room much fouler, if possible, than it went out. This reminds one of pumping little jets of pure water in all over the bottom of a muddy reservoir, by which the whole mass is kept in a constant roily, muddy condition.

There seems to be an entire unanimity among all parties as to the necessity for additional moisture. This I think of much importance.

I however doubt the propriety of allowing the steam to be discharged directly into the fresh-air channels. There is often an unpleasant smell from escaping steam, and more frequently from the air driven from steam-pipes as the steam enters. This could be tried, however, very easily, and it might not be found objectionable.

Although not directly connected with the subject of ventilation, yet I would take the liberty of suggesting that I think there is a deficiency of sunlight in the hall of Representatives. The sun's rays are the great source of purification, the great natural disinfectant, as well as the great moving power in the growth and development of all animal and vegetable life. We find cretinism and imbecility to predominate greatly on the shady sides of the mountains. In the Russian barracks it was found that sickness and mortality were much greater on the shady side than on the sunny side, even of the same large room.

The great value of an abundant sunlight was most fully demonstrated throughout our own very extended system of barracks and hospitals occupied during our late war.

I would by no means intimate that I believe the ingenuity of man can never produce these chemical life-giving influences the same as he has already produced light almost equal, for his own limited purposes, to the great source itself. And it was certainly very creditable in the original projector of the buildings to endeavor to be as independent of all external influences as possible, and to rely as much as he well could on man's own ingenuity and resources.

But as the chemist or philosopher has not yet learned to make so much as a clover-leaf or a caterpillar, would it not be well for the present to go back to the old-fashioned plan and use a little more sunlight for the purification and disinfection of the rooms under consideration, while the chemists and philosophers are perfecting their plans, especially as sunlight can still be procured quite cheap, and is one of the few comforts of life that have not been doubled or trebled in price since the completion of these rooms. I think if a little ingenuity were exercised upon it there would be but little alteration required and not much expense incurred in introducing sufficient to produce a very perceptible influence.

As this building is entirely different from any other building in the world, and the knowledge in regard to the subject of ventilation is still so limited, it would seem to me to be wise on the part of Congress to employ the best talent and practical experience the country affords, to make a thorough examination and such experiments as they might require for the full illustration of the subject, and have them report in full the present condition of the ventilation, heating, and lighting, and such suggestions as they might have to make for the improvement thereof.

I believe such information could thus be procured as would enable Congress to act with much more confidence, and would produce results much more satisfactory than to act upon any information it now possesses.

I am, with much respect, thy friend,

LEWIS W. LEEDS,
Consulting Engineer of Ventilation and Heating,
for United States Treasury Department, &c.

WASHINGTON, 1*st Month* 13, 1868.

Additional report.

To the Hon. JOHN COVODE,
Chairman of Committee on Ventilation of House of Representatives:

Since making the foregoing report I have made a large number of experiments to determine the temperature and direction of the currents in various parts of the building.

I commenced at half-past 12 on the 5th, and tried sixty-three experiments in the loft over the House, in various parts, to determine the directions of the currents there, a memorandum of which I inclose, marked 1, 2, and 3.

I also took the temperature in twelve different places in the loft, a memorandum of which is also inclosed, marked 4.

On the morning of the 6th I commenced an examination of the position of the registers on the floor of the House, at ten minutes of 10 a. m., and also took the direction of the currents at top and bottom of all the doors opening into the hall; also, the direction of the currents in twenty-seven other places in various parts of the hall; also, the temperatures at seven different points around the side of the hall. Memorandums of these experiments are also inclosed, marked 5, 6.

On the morning of the 7th I went to the House at a quarter past 7 a. m., for the purpose of ascertaining the temperatures in the loft over the hall; but as the workmen had the keys, and did not get them until half-past 8, I could not test the temperatures until 9, the sun being then two hours high; clear, bright day. The results are inclosed, as well as the temperatures in the galleries and around the sides of the hall, as observed at the same time.

I had no expectation of finding the supposed conditions noticed in the preceding report (which were based upon mere theory) so nearly correct, and capable of being so clearly and fully proven by these experiments.

It will be noticed by the experiments on the 5th that the temperature in the loft was 44° and 48°, at 3 p. m.; on the 7th, at 9 a. m., it was 38° on the east end, and 45° on the west end.

The experiments of the 5th show that there was a strong descending current all around the exterior of the hall, excepting the west end, from the loft into the hall, and the experiments of the 6th show this current carried over the galleries and tumbled down onto the floor of the House. The other experiments show that there is a strong current rushing in from the corridors, through all the doors, without exception, both on the floor and on the galleries.

Now, when we consider the corridors are the principal ventilators for the engine-room, restaurant, water-closets, &c., &c., and then add to this most of the foul air from the galleries, it will be seen that the floor of the House is the final receptacle of all the washing of the building, and is the foulest pit of the whole.

It will also be observed that the current is from the east side towards the west side, and there rises to the attic, and much of it from there flows across to the foul-air shaft; consequently about the center of the west side is the place where the air leaves the occupied portions of the building, and probably that is, therefore, about the foulest place in the whole building.

An examination of the condition of any of the registers will convince any member as to how much relief he can expect from them. The accompanying diagram, showing how many of the registers were open and how many closed, is merely an approximation, as so many of them were so choked up with tobacco spit, sweepings of the floor, and other trash, and there was such a foul smell coming from them, that it was difficult to determine whether to consider them closed or open.

I should think it would be well to try the experiment of reversing the fan and drawing the air *from* the floor instead of *forcing it in*; but with the present arrangements for heating and supplying fresh (?) air, it would probably merely aggravate the difficulties.

The little positive knowledge thus gained by the few experiments already tried more fully convinces me of the necessity for and value of a series of experiments, extending over a month or six weeks, and taken under all conditions of wind and weather, and when the house is crowded and when but few are there.

An entirely different condition of things will probably be found to exist when the whole lighting apparatus is in full blast.

Very respectfully,

LEWIS W. LEEDS.

WASHINGTON, D. C., *2d month* 8, 1868.

SMITHSONIAN INSTITUTION,
Washington, January 17, 1871.

DEAR SIR: * * * * * * *

I have examined the glass as to translucency, and find that the figured pattern absorbs about one-half of the light, while the plain, varnished specimen absorbs only about one-fourth.

I have the honor to be, very respectfully and truly, your obedient servant.

JOSEPH HENRY,
Secretary Smithsonian Institution.

HON. THOMAS A. JENCKES,
United States House of Representatives.

110 BROADWAY, NEW YORK, *5th month* 3, 1870.

To the Joint Committee on Ventilation :

GENTLEMEN : In experimenting with a view to the improvement of the ventilation of the halls of Congress, I think it would be very desirable to ascertain the general movement of current in the whole building as a mass, and see what are the great natural causes of motion or agitation.

I think the central dome will be found to exert a great influence, extending to both houses of Congress. Then to ascertain the more local causes of disturbance in various places, and to trace the currents to sources of contamination when such occur. Also, to note carefully the influence both of external temperature and the directions and force of external currents. Then to examine the artificial means of producing currents both by the fans and the heated shafts, and to measure carefully their relative value for moving the air in proportion to fuel consumed. These currents can be best measured and recorded by carefully-made anemometers.

It would be well, I think, to make a careful record of the hygrometric condition of the air, which could be done by one or two hygrodeits.

One of the greatest sources of annoyances, I think, is the variations of heat and cold from the lighting apparatus, and the exposure of the metal roof to the accumulation of snow, &c.

I think a careful record of the temperature of the space under the roof when the gas is lighted, and at other times, would be valuable.

Very respectfully submitted.

LEWIS W. LEEDS.

Report accompanying plans for the improvement of the ventilation and heating of the hall of Representatives by Lewis W. Leeds, engineer of ventilation and heating, 110 Broadway, New York.

That, to warm a room by direct radiation, and supply it by cool, fresh, invigorating air for breathing, is necessary for health and comfort, is now so generally admitted that it scarcely needs any argument in its favor.

The great wonder now is, that so many very eminent engineers should have persevered so long directly in the face of continued failures in attempting to warm and ventilate large buildings by forcing in currents of overheated, debilitating air, at the same time allowing all the walls and solid objects in the room to be colder, and absorbing the animal heat—the very essence of life—from the inmates. The cause of these universal failures is well explained by the simple physiological fact that we give off twice the quantity of carbonic acid, or, in other words, that we live twice as fast, and can do double the amount of work, and need as much again food when we are breathing air from 10° to 20°, that we do when breathing air from 90° to 100°. This is well illustrated on any bright, cold day : the warm rays of the sun, which are frequently of sufficient power to boil water, are very agreeable as they fall upon us while we are surrounded with and breathing the cold and invigorating air perhaps at 20° or 30° ; vigorous bodily or mental exercise is then much easier than on a sultry day in summer.

How entirely different are the conditions now existing in the house of Representatives. The air is taken in at the basement, down through the cellar : from there forced up by the fan through an immense stack of rusty, dirty iron pipes, coated by many years' accumulation of particles of decaying animal and vegetable matter, roasted up afresh every day ; from thence driven through a labyrinth of uncleaned horizontal air-ducts, filled with the molding and decaying dirt of several years' accumulation ; and finally driven through the uncleaned spittoons arranged all over the floors of the house, issuing into the rooms at a temperature of 100° to 120°, a warm, filthy, disgusting mass for the members to breathe. I think it is time this was changed.

Not only does the application of direct radiation furnish a much more wholesome and agreeable atmospere, but it at once relieves us of much of that trouble about the proper circulation of the fresh and foul air that have so vexed the hot-air engineers. It enables us at once to dispense with those expensive nuisances, the fans. Most of the members no doubt have noticed the disagreeable smells and heat arising from the engine-rooms, and fans, and which fill the western stairways, especially on the side of the Senate. At times in the summer, when the doors are open and the wind from the south, this unpleasant odor and heat may be noticed on the east front—having filled the whole stairway, passed across the Senate chamber, and out the front. In summer this current adds several degrees of heat to the temperature of the upper rooms. By dispensing with the engines and fans a great gain would be at once effected, both in economy and comfort.

I know very well that many prominent engineers insist upon it that the fan is necessary to secure at all times the proper circulation of air. When dependence is placed

exclusively upon warming the whole building by currents of heated air, (which is all wrong,) there may be some excuse for the use of the fan, but I think even then the heated shaft is more efficient. All question is avoided, however, as to the necessity for its use where we heat principally by direct radiation. The idea of heating by direct radiation is by no means a new one; it is much older than heating by hot-air currents.

But perfect success depends greatly upon the proper and skillful arrangement of the heating surfaces, in combination with the necessary supply of fresh air and the removal of foul, so arranged that a uniform movement of air shall be secured over the whole building without perceptible draughts.

Probably four-fifths, or not unlikely nine-tenths of all the air entering the building as now arranged comes in through the doors and windows; the other one-fifth or tenth being driven in by the fan, frequently at a high temperature, to counteract the cooling effect of that entering by the doors and windows. Now, by placing the heating surface directly under the external windows, that *really* becomes the very best place for the supply of fresh air. It enters then directly from the external atmosphere, thus avoiding the great objection to long, uncleaned air-ducts.

By leaving the heating surface exposed, we get the greatest direct radiation just where it is most needed—immediately under the cold window; the two extremes thus neutralizing each other. This arrangement was suggested by me, adopted by the Supervising Architect, and has been tested in the north wing of the Treasury, and with subsequent modifications in New York. It is found to work admirably. Those unpleasant cold draughts so commonly felt near windows are thus entirely prevented. The plans accompanying this report show where it is proposed to place the heating surface in the various stories.

I was surprised and very much pleased to find how readily an entire modification of the heating and ventilation could be effected without disturbing the general arrangement of the building in any important particular. It will be observed by reference to the plans that it is proposed to completely reverse the direction of the currents at the floor; and instead of the fresh (?) air entering through the uncleaned spittoons as at present, the foul air will be drawn off there. This change can be effected without at all interfering with the present arrangement of the supply by the fan—so that it may be reversed in fifteen minutes, and the fan can be used every alternate day until it is fully proved to be worse than useless.

It is proposed not to touch the present arrangement in any manner, but to leave the whole just as it is, to be used at any time to illustrate more strikingly the contrast. The old material would be of little value if removed.

SUPPLY OF FRESH AIR.

In previous reports much stress has been laid on the source of supply for the fresh air. Most of them contemplate conducting through underground passages of considerable length. I endeavor to avoid all underground air-ducts whenever possible, as the difficulty of keeping them sweet and pure is so great that it is seldom done in practice. Any damp place excluded from the direct disinfecting and purifying rays of the sun is liable to become mouldy, and this mould of such places is now considered to be the cause of miasmatic fevers.

When it is proposed to force the air over the entire building by fans from one or two points, this single supply may be of considerable importance; but with the heating surface distributed around the entire building as proposed by us, the difficulty is entirely overcome at once, and we admit the pure external air directly into the building without the least contamination.

And for the hall of Representatives we propose taking the pure air from the very top of the building—a higher point than proposed by any of the other parties. This fresh air will enter through the numerous perforations of the panels in the ceiling, and being *cooler* will fall gently diffused over the room; and as a large proportion of the heat will be derived from the direct radiation of the warmed walls, the effect will be very similar to that of a cool, bright day in spring or autumn.

Many persons suppose that a current of cold air on the head would be unbearable. This depends entirely on attending circumstances. I have frequently stood on the hot plates in the hold of a steamship, with my back to the hot boiler, and allowed a perfect torrent of very cold air to pour down upon me. The effect was delightful as long as my feet and back were kept thoroughly warm. But if you are surrounded by cold walls and a cold current strikes your back, especially between the shoulders, or makes the feet cold, that is very dangerous.

REMOVAL OF FOUL AIR.

With many of the projects for ventilation this seems to have been the primary object, but it is really secondary, the supply of the fresh air being of the first and greatest importance.

If a building is constantly overflowed with an abundance of cool, fresh, invigorating

air, and has an ample supply of heat from well-diffused heating surfaces around the exterior to prevent the inconvenience of cold draughts, there will be but little difficulty about the escape of the foul air.

It is better, however, and makes a more perfect arrangement, to provide for an ample and regular removal of foul air, sufficient to keep the rooms perfectly pure, even should all the windows and doors be closed for a long time continuously. By reference to the accompanying plans it will be seen that this is fully provided for.

In the first place, it is necessary to remove with care all offensive smells. With the present arrangement the heat, gases, and odors from the boiler and engine rooms are about the greatest nuisances in the building; then the heat and smell from the kitchen and restaurant in the cellar, as well as from the water-closets, permeate the whole building. All these would be carefully removed by the four large shafts connected with the smoke-stacks from the boilers. These are now doing very efficient service, but the odors from the boiler house, &c., ascend the main stairs, flow through the hall of Representatives across the attic down two of these flues to the bottom of the cellar again and up the other two and finally escape. Rather a circuitous route to make the foul air travel. Reminds one of the undertaker who carried the body of a person having died with the small-pox all through the town to show the people how careful he was in burying such. Instead of this we would propose, as shown on the accompanying plan, to open all four of these large flues directly from the cellar and engine-house, using three for the ventilation of the latter and one for the kitchen and water-closets. This will double the capacity of these flues, as the two now used for bringing the air down from the attic would be capped out above the roof, and make most efficient exhaust flues from the cellar and basement. The two on the eastern side would require a steam coil or furnace in each to increase the draught. The heat from the boilers causes an excellent draught in the others, as may be easily seen at any time on examination.

The capacity of these flues at 50 square feet area, with a velocity of 5 feet per second, would give a discharge of 15,000 cubic feet per minute, which would be about equal to the working capacity of the smaller fan.

Now, with this large exhaust from the cellar and basement, removing these offensive smells, one-half of the present difficulties would be removed. There would be much of the time a descending current on the main stairs, where there is now an ascending current.

The space behind the main stairs on the east front should be one-half used for a ventilating shaft from the cellar and basement at that end of the building, and the other half for an air-duct for forcing up cooled air for summer and for a hoist-way for ice, &c. The space behind the main stairs on the west, where the steam coils are, should be used as a ventilating shaft exclusively, for the discharge of foul air from the floor of the house. By shutting off all supply from below and opening an outlet above, as shown on the accompanying section, the whole current would be at once reversed; so that, instead of the current entering at that point, the foul air would be drawn off there, as it should be. This flue is 6 by 30, giving an area of 180, which, with a velocity of 4 feet per second, would discharge over 40,000 feet per minute. This in addition to the large amount that would be escaping from the ceiling at all times, and especially when the gas was lighted, would be double the quantity that would be generally required, and consequently must be throttled much of the time.

It is proposed to alter this main shaft in such a manner that it can be replaced in a short time, so that instead of its being an exhaust shaft it will be a supply shaft, just as at present. Where the fresh air supplied is colder than the temperature of the room, and the heat derived from direct radiation, a much less number of cubic feet answers for a healthful respiration; yet it will be seen we have a capacity for the discharge of air double the amount required under any circumstances whatever.

SUPPLY OF COLD AIR FOR SUMMER.

By removing the engines and fans, or allowing them to remain cold, one-half the trouble in this respect will be obviated, and by ceiling the space under the roof, as shown on the transverse section, also making a double ceiling over a large part of the main hall, will greatly improve the building in that respect. Also the thorough isolation and more complete ventilation of the lighting loft will relieve the main room of one very great trouble now existing, that is, the return of the air from the loft, loaded with the products of combustion and escaping gas, down over the galleries on to the floor of the House. By a series of experiments tried last year this was shown to be the constant action on three sides of the room.

It is believed that when these improvements are all made there will be but few days in the year when a forced ventilation (without the heating) would not be sufficient to keep the building comfortably cool.

The plans as submitted admit, however, of the most complete arrangement for cooling the air for ventilation. The cooling apparatus can be placed in the cellar near the

eastern end, and the cooled air driven up the shaft left for that purpose, as shown on the plan, or, perhaps better, the whole apparatus could be placed in the attic over the corridors and stairway, and if ice was used, it could be hoisted up the place shown for that purpose, or if water was used for cooling, it could be pumped up and used then.

DIRECT ADMISSION OF EXTERNAL AIR AND SUNSHINE TO THE HALL OF REPRESENTATIVES.

The opinion seems very prevalent that there is an absolute necessity for the admission of the external air directly into the hall, as well as the direct rays of the sun to give that freshness and vigor as well as purity to the contained atmosphere so desirable. There are, no doubt, good grounds for this opinion. There have been propositions for very considerable structural changes which would involve very great expense at the present high price of labor and material.

The suggestions we make, however, are very simple, not interfering in any way with the construction, and although not strictly architectural, perhaps, but as they are so insignificant and kept below the line of the balustrade they cannot be seen externally from any ordinary point of view. But in this very simple manner we let in a large amount of additional light, greatly needed on cloudy days, allow of the direct admission of an abundance of fresh air from the very top of the building, which is much more desirable than at any point near the ground, and, above all, allow of the admission of a very considerable amount of the direct rays of the sun.

SUMMARY.

If the suggestions herein contained are carried out according to the accompanying plans, the following advantages will be gained:

1. A cool, fresh, invigorating air over the whole building in place of the warm, overheated, debilitating stuff with which the building is now filled.

2. A gentle, well-diffused warmth from direct radiation, which is entirely different from and superior to the warmth derived from currents of heated air.

3. The feet and the backs of the occupants will be kept really warmer than their heads.

4. The hall of the House of Representatives will be overflowed with an abundance of pure external air with a much better light, and the admission of a considerable portion of the direct rays of the sun, never before admitted since its completion.

5. The whole apparatus for heating will be very nearly self-acting, as it is so thoroughly distributed on the external sides of the building no matter which way the air moves. North, south, east or west, or up or down, the warmth is nearly uniform, as currents of air do not affect radiant heat.

LEWIS W. LEEDS,
Engineer of Ventilation and Warming, 110 *Broadway, New York.*

3D MONTH, 16TH, 1869.

TELLIER'S REFRIGERATING OR AIR-COOLING MACHINE.

[To accompany drawing presented to Committee on Ventilation April 28th, 1879, by H. R. de La Reintrie, sole agent.]

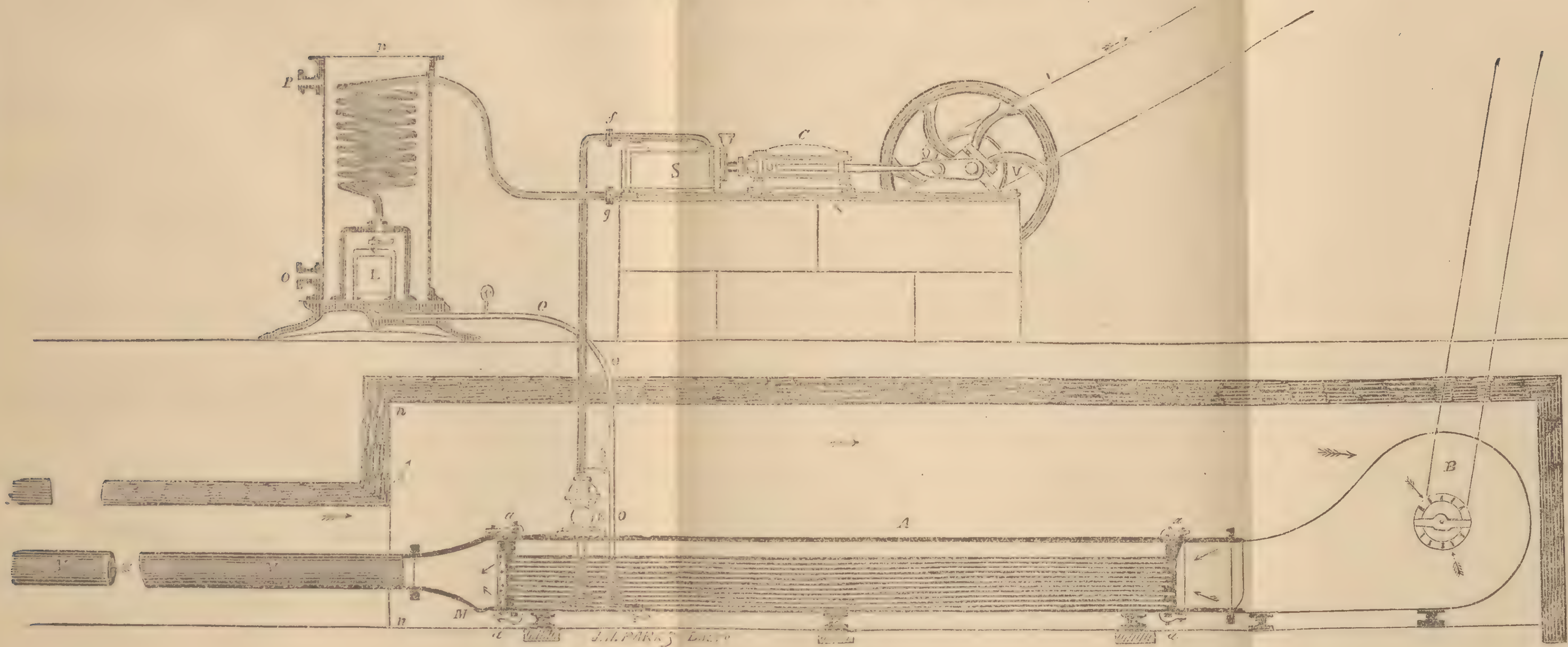
Refrigeration produced by means of ice is necessarily imperfect and unsatisfactory. The action of the ice cannot be uniformly distributed throughout the room, but is felt more or less, according to the distance from the masses of ice. After a short time the ice in melting becomes so closely packed that the air ceases to circulate between the blocks, so that precisely as the season advances and the cooling action becomes more indispensable, the desired effect of the ice becomes less and less. Moreover, the atmosphere produced by this means is damp, moist, and heavy, and ill-adapted to the preservation of animal or vegetable matter. These inconveniences are all overcome by the machine which I am about to describe, the simple object of which is to produce cold air, and to drive it into the rooms to be refrigerated by means of a ventilator or fan. This machine presents four principal parts, viz:

I. A refrigerating cylinder, A.
II. A ventilator, B.
III. A compressing pump, C.
IV. A condenser, D.

The refrigerator A is a strong iron cylinder, closed at each end, *a, a, a, a,* within which are lodged a number of small tubes from one-half five-eighths inch in diameter, part of which may be seen in *x, x, x, x.* All these tubes open freely into the atmosphere at both extremities of the cylinder. The latter is closed at each end by a metal disk, through which pass the extremities of the tubes *x, x, x, x,* so that whilst the interior of the latter is left perfectly free, the space circumscribed by the tube A

TELLIER'S REFRIGERATING MACHINE,

Patented, January 5, 1869.



A. REFRIGERATOR.

B. VENTILATOR.

C. COMPRESSING PUMP.

D. CONDENSER.

NOTE:—The chemical used is Mythelic Ether or Gas of Ammonia, which is *confined* within the apparatus and cannot escape.

It is vaporised by means of the air driven through the Refrigerator: thence, the vapors rise and are drawn into the cylinder of the Pump: there compressed, heated and driven into the Condenser: there condensed and returned, in a liquid state, to the Refrigerator.

The operation of the Machine is *continuous*. It ranks to-day as an Exact Science and Industrial Art.

H. R. de La REINTRIE,

Sole Agent for Maryland and District of Columbia, May 4, 1870.

and these disks forms, nevertheless, a strong and perfectly tight chamber. That this result may be the more perfectly obtained, a strong iron band, seen at each extremity, *e, e, a, a*, is welded on the cylinder, and thus strengthens the ends. The whole arrangement, being then carefully tinned and soldered, is heated and covered over with a coating of solder one-fourth to one-half inch thick, so that the whole forms one solid mass, without the possibility of any leak, as there are neither rivets, joints, nor nuts, save the two tubes of the cocks E and F, which are, themselves, set so as to form integral parts of the tube A.

I have nothing special to say of the ventilator B, which may be of any approved pattern.

The compressing pump C is worked by means of a belt passing over the block V. Its cylinder presents no other peculiarities, save that the valves, contrary to the prevailing custom, are placed: 1, the exhaust at the upper part of the cylinder, corresponding to the tube *f*; 2, the force valve, at the lower part of the same, corresponding to the tube *g*. By means of this arrangement, should any liquid be formed by condensation in the cylinder, it will be removed at every stroke of the piston. This cylinder is of cast iron, with an outer jacket, through which circulates a current of cold water, the object of which is to carry off the caloric produced by the compression. A cock, S, regulates the introduction of this water. The condensing column D is composed, 1, of a coil, G; 2, of a chamber containing a float, L, into which flows the product of the condensation. (See note at end.)

The refrigerator A, being now filled with methylic ether, liquefied ammonia, or some other analogous fluid, which completely surrounds the tubes *x, x, x, x*, if a continuous current of air be driven through these tubes by the ventilator B, that liquid is rapidly vaporized, carrying off with its vapors the caloric contained in the air, and thus causing an equally rapid lowering of its temperature. A degree very near to freezing point may thus be reached, but must not be passed. The abundant condensation which takes place in the tubes would then change *into ice*, and by obstructing them would soon clog the working of the apparatus. *By merely getting to a point near 32°, the result is only an abundant condensation, the product of which may be drawn off through the tube M. The air, thus refrigerated, escapes through the conduits N N, and may then be distributed at will. I now return to the volatilization of the volatile liquid which takes place in A, the vapors escaping through the valve E. If the vapors thus formed escape freely into the atmosphere, the desired effect would be reached, but the vapors would be lost and the expense arising from this fact would make the operation, commercially, impracticable. On the other hand, if they were sent directly into the condenser D, condensation could not take place, because the temperature of A, being lower than that of D, the pressure would at once equalize itself to that of the cold vessel, and could not produce in D the maximum tension necessary for the condensation. Such is precisely the result brought about by the compression pump G. Under the influence of the motion which it receives from the belt, its cylinder fills with the vapors produced in A, which are compressed by the piston and forced into the condenser as soon as the pressure is sufficient to cause condensation. That the latter may take place in a constant manner a continuous current of cold water is brought through the tube *o*, going out through the tube *p*, after bathing the reservoir L and the coil *a*, thus carrying off all the caloric of condensation. As fast as the vapors are condensed, they are gathered in the chamber which holds the float L. When the quantity is sufficient, the liquid raises the float, and passing through the tube *o, o, o, o*, flows back into the refrigerator A. Thus constant vaporization may go on in the tube A, without reducing the level of the methylic ether or liquified ammonia, which fact secures the continuous working of the machine. A glass level may be made to connect the tubes E and F, and thus facilitate the verification of the condition of the tube A, which should always contain enough liquid to bathe completely the tubes *x, x, x, x, x*. I will now proceed to explain how the air, to be cooled, may be obtained. If this were drawn from the outer atmosphere, the machine, especially in summer, would be called upon to perform a tremendous task, the external temperature at that season reaching frequently as high as 90° and over. To avoid this inconvenience it is the atmosphere itself of the rooms which is drawn. To accomplish this, the refrigerator A and the ventilator B are both lodged within a chamber, open at one end, so as to allow the passage of the conduit N and the free admission of air into the chamber. There is thus a direct communication established between the rooms to be refrigerated and the chamber of the ventilator B. This opening being disposed at the upper part of the room, it is always the warmest air that is drawn, driven by the ventilator through the refrigerator A and discharged at the lower part of the rooms. Thus is established a continuous circulation of the same fluid mass, which, being discharged cold at the lower part of the rooms, absorbs the caloric which comes in contact with it, dilates, rises, carrying off this caloric, passing through the ventilating chamber into the refrigerator, where it again leaves off the caloric, and so on; the air being, in fact, but a mere vehicle for the heat which it alternately takes up and leaves off. Fears have been expressed that this constant circulation of the same air would not keep the atmosphere of the

rooms sufficiently pure. There need be no apprehension on that score. In the first place it is customary, whenever it is desired to keep a room cool, to keep it closed as tightly as possible; now to leave the air stationary or to cause it to circulate can make no possible difference. In cases where there is formation of carbonic acid gas, (as is the case in brewers' fermenting rooms,) it is perfectly easy to get rid of it, by mitigating the current with a certain proportion of fresh air, which will drive off a like quantity of vitiated air, and, in a given time, will completely renew the interior atmosphere. But this is not all; instead of being a cause of alteration, this circulation, on the contrary, produces a constant purification of the air. Under the influence of the absorption of the caloric, the hygrometic condition of the air is modified, and all the vapors it holds in suspense are condensed. This phenomenon leads to this consequence, that all the miasmas or impurities which might be in suspense in the air are carried off with this condensation. Thus the air is discharged purified, dried, and in the most favorable conditions for the absorption of such new vapors or miasmas as might be formed, which, by its continuous circulation, it will constantly carry off, leaving the interior atmosphere as pure and as cool as possible. The drawing, (sheet II,) shows the conduit N, as opening at the entrance of the cellar; it is hardly necessary to observe that this disposition, made necessary by the compulsory limits of a drawing, should not be carried out in practice, and that the cold air should be carried and discharged at the opposite extremity of the room, so that it may be compelled to pass through its entire extent before returning to the chamber of the ventilator; in this manner the desired effect is obtained in the most perfect manner.

H. R. DE LAREINTRIE,
Sole agent for the District of Columbia.

BALTIMORE, MD., *May* 4, 1870.

NOTE I.—The float L, at the base of the condensing coil, which is intended to regulate the flow of the liquid back into the cylinder, has been replaced by a patent spring cock, which effects the same object, whilst permitting at the same time to regulate exactly the pressure in the machine, and consequently to control perfectly its action.

NOTE II.—The lubricating cup, which appears on the compressing pump, and which is intended to lubricate the piston rod of the said pump, is so contrived as to act at the same time as a trap, to catch any vapors which might escape in that direction. As this is the only point where, from the peculiar construction of the machine, there could possibly be any leak, this contrivance effectually removes all such possibility.

Respectfully submitted.

H. R. DE LAREINTRIE,
Sole Agent for District of Columbia.

May 4, 1870.

I also refer the honorable Committee on Ventilation to Barnard's reports on the Paris Universal Exposition, chapter xii, pages 361 to 402, a valuable work.

LAREINTRIE.

OFFICE OF THE UNITED STATES (TELLIER)
ICE AND REFRIGERATING COMPANY,
61 *Broadway, New York, February* 16, 1871.

DEAR SIR: At the request of an agent for the District of Columbia, Mr. H. R. de La-Reintrie, of Baltimore, I beg to submit the following estimate of the expense of erecting and fitting up the Tellier refrigerating machines for the purpose of cooling the Houses of Congress. The object which it is proposed to accomplish is to reduce the temperature of the corridors surrounding the two halls some 20° below that of the outer atmosphere. These corridors, according to the figures obtained in the office of the architect of the Capitol, measure, in the aggregate, that is, both the upper and lower corridors, 184,019 cubic feet, or 6,818 cubic yards for the south wing, and 152,623 cubic feet, or 5,653 cubic yards, for the north wing, exclusive of the connecting corridors. The first step will be to isolate and protect as effectually as possible against the action of the outer atmosphere the parts to be so refrigerated. To that effect, partitions with double swinging doors must be erected at each end of the connecting corridors, and every door and window leading out from the corridors kept as securely closed as in winter. Communication, however, between the upper and lower corridors should be kept as free as possible in order to insure perfect circulation and thorough ventilation. The cold air coming from the machines will be discharged at the bottom of the lower corridors, where, mixing with the warm air, it will rise, passing into and through the upper ones to the ducts of aspiration which will be located in the latter, and at the fartherest possible point from the orifices of the discharge. Thus, there will always be maintained a gentle upward current which will constantly carry off whatever heated or vitiated air may rise from below, leaving the atmosphere as pure and as cool as pos-

sible. For it must not be forgotten that the process not only cools but purifies the air, and for this reason no apprehension need be felt on the score of the rooms being kept closed, as the atmosphere within will always be purer than that without, besides keeping out the dust, &c.

Apparatus will be required for each wing of sufficient capacity to discharge 10,000 cubic yards of cold air per hour at the temperature of 34° to 35° Fahrenheit. Were there no accretion of heat whatever into the corridors save that arising from natural radiation, this would maintain a temperature of 40° to 45° Fahrenheit; but in the present instance, with more or less caloric constantly pouring in from the floor and galleries of the Houses, and by the frequent opening of doors, 70° to 75° will be as much as may be expected, that being about the most comfortable temperature for the human frame, and such as usually prevails at Newport, Rhode Island, during the pleasantest weeks of the "season."

The total expense of applying and fitting these machines to both Houses of Congress I estimate as follows:

Refrigerating machines of the capacity named above, one for each wing, at $37,500	$75,000 00
Brick and woodwork, air conduits, &c., and to be executed according to our instructions, but under the direction of the Architect of the Capitol, if desired, for each wing $10,000	20,000 00
Contingencies	5,000 00
Total estimated outlay	100,000 00

These figures, save as to cost of machines, are mere estimates, and it is probable that the expenses covered by the second item will never reach that figure, nor is the last item likely to be called upon at all. A portion of the machinery will be brought from Europe. Should the Government see fit to remit the duties on same, the amounts thus remitted shall be deducted from the above figures.

The machines are to be located in the basement, and will each require a maximum motive-power of 25-horse. Each machine will also require a supply of water for purposes of condensation of 1,200 to 1,500 gallons of water per hour and will be provided with pumps of sufficient capacity to furnish the said supply; this water is in no wise injured by the process, its temperature being only raised some 4° or 5°, and may be conveyed anywhere to be used again for this or for other purposes. The machines complete will each weigh not to exceed 8 to 10 tons, and will occupy a space of about fifty feet in length by six feet in width; more, however, should there be a lack of height.

In making the appropriation to carry out the purposes of this estimate, I respectfully beg that one-third (33⅓ per cent.) of the first item, or amount required for the machines proper, be paid in advance upon the execution of a satisfactory contract.

All of which is respectfully submitted.

L. BOUVIER,
Acting President.

Hon. THOMAS A. JENCKES, M. C.,
Chairman Committee on Ventilation, Washington, D. C.

AGENCY OF THE TELLIER ICE AND REFRIGERATING COMPANY,
No. 34 *Post Office Avenue, Baltimore, February* 18, 1871.

DEAR SIR: Under date of yesterday Mr. L. Bouvier, now president of this company, informs me that on the 16th he mailed to your address the estimate of the cost of cooling the two wings of the Capitol building, in Washington, and which I trust you have already received.

At my request he has placed the estimate at the low figure of $100,000, that being one third the amount proposed in the estimate of May 11, 1870, for cooling the two halls of Congress.

The machines will be constructed with the utmost care and in the very best style, will be highly finished and ornamented, with walnut casings, silver bands, &c., &c., so as to make them an object of admiration to the eye as well as to the mind. Of their efficacy and utility in the Capitol of the nation, I have no doubt whatever. We have put the price low, in consideration of the great benefits to accrue to us hereafter from their being thus prominently brought before the public.

Hoping the present estimate will meet the approbation of the committee, of which you are the distinguished chairman,

I am, sir, very respectfully, your obedient servant.

H. R. DE LAREINTRIE, *Agent.*

Hon. THOMAS A. JENCKES, M. C.,
Chairman Committee on Ventilation, Washington, D. C.

WASHINGTON, *February* 2, 1871.

DEAR SIR: At the suggestion of Mr. Jenckes I beg to state that we can, if desired, furnish you with a current of air from two of our machines, one for each House, at the temperature of 33 to 34° F., to be distributed or used as you may deem proper. The amount of air thus furnished will be of 75,000 to 100,000 cubic feet per hour for each House, and there will be required 18 to 20 horse-power, exclusive of the power required to fan the air into the dome. The cost of this would be about $25,000 for each House, and our principal profit from such an undertaking would be the advertisement we would get thereby. Will you be kind enough and see Mr. Jenckes in the course of the day, and see if you can come to some understanding with him in the premises.

Yours, truly,

L. BOUVIER.

EDWARD CLARK, Esq.

Mr. L. Bouvier, New York, and Mr. de LaReintrie, Baltimore, called to see Mr. Clark; will return again at about 11 o'clock a. m.

UNIVERSITY OF MARYLAND, *March* 28, 1870.

SIR: From what I know of the principle and the construction of the Tellier "refrigerating machines" and "ice machines," and from the results of their actual use in Europe, where they have been thoroughly and severely tested, they will, in my opinion, accomplish all that is claimed for them in your circular.

WILLIAM E. A. AIKIN, M. D., LL.D.,
Professor of Chemistry, &c., &c., &c.

H. R. DE LAREINTRIE, Esq.

COLUMBIA COLLEGE, NEW YORK,
President's Room, June 13, 1870.

DEAR SIR: I owe you an apology for not having sooner acknowledged your very complimentary letter of the 2d instant. There has been so unusual a pressure of occupation upon my hands as to throw all my correspondence into arrears.

I am very much gratified to see that the admirable inventions for producing intense cold, artificially, are beginning to be appreciated in this country as well as abroad, and I have no doubt that they are destined to be productive of very great public benefit. That of Mr. Tellier, in which you are interested, has great capabilities, and promises, I think, to be not only useful, but profitable to those who employ it. Meantime there seems to be springing up some controversy* among the different patentees in regard to their respective claims to originality. I sincerely trust that this may not be the occasion of preventing the public from reaping the full advantage which any one of these beautiful processes is capable of bestowing.

With my best wishes, I remain, very respectfully, your obedient servant,

F. A. P. BARNARD.

H. R. DE LAREINTRIE.

NEW YORK, *October* 20, 1870.

DEAR SIR: After spending nearly two weeks in making an exhaustive and critical examination of your Tellier ice machine, (No. 4,) now working at the Morgan Iron Works, and watching its operation through as trying circumstances as an ice machine ever worked, and seeing it produce ice at the rate of 100 to 120 pounds *per hour*, I have no hesitation in stating that I consider this machine the simplest and by far the cheapest as to construction, while the process itself is actually the most economical, in producing artificial ice, of any in use.

I have come to this conclusion after managing as chief engineer, for three years, the large works of the Louisiana Ice Manufacturing Company, in the city of New Orleans, where *six* large Carré's machines are in operation, and after examining critically *all* other machines now offered in the United States.

Respectfully, yours,

THOMAS F. PETERSON,
Chief Engineer Louisiana Ice Manufacturing Company's Works, New Orleans, La.

L. BOUVIER, Esq.,
Secretary United States Ice and Refrigerating Company.

* There is none about the Tellier patent. Professor Twining, after seeing the ice machine at work in New York, September, 1870, admitted that Tellier's machine was different and far superior to his, (Twining's,) never fully developed.

H. R. DE LAREINTRIE.

OFFICE No. 61 BROADWAY, *New York, October* 20, 1870.

MY DEAR SIR: Inclosed herewith I send you a letter addressed to the company by Thomas F. Peterson, chief engineer of the Louisiana Ice Works in the city of New Orleans, giving his opinion of the merits of the Tellier ice machine. This, from the man who is the chief of the only ice works in the United States making 72 tons per diem, is praise indeed. He thinks it far superior to all other ice machines, and he has examined all, and knows more about ice machines than any man in this country. He is exceedingly enthusiastic about it, and has been up to the works every day and all day for the last two weeks.

What will Messrs. Carré & Co., do you suppose, say now? He is just as ardent an admirer of our refrigerator.

Very truly, yours,

SAMUEL C. REED,
President.

To H. R. DE LAREINTRIE, Esq., *Baltimore.*

The foregoing are true and correct copies of the original letters now in my possession.

H. R. DE LAREINTRIE,
34 *Post Office Avenue, Baltimore.*

FEBRUARY 8, 1870.

OFFICE OF BALTIMORE AND TEXAS STEAM TRANSPORTATION CO.,
No. 34 *Post Office Avenue, Baltimore, May* 14, 1870.

SIR: I have the honor to inclose, herewith, the following papers and drawings, viz:

No. 1. Proposal and estimate of the "United States Ice and Refrigerating Company," of the city of New York, of the expense of refrigerating and ventilating the two halls of Congress; the descriptions of "Tellier's refrigerating machine," the drawing of which was left with your committee on the 28th ultimo, and the specifications thereof, subsequently mailed to your address.

No. 2. Drawings, by Professor Seager, of the "spring cock A," and lubricating cup B, part of the machine.

No. 3. Descriptions of said spring cock A.

No. 4. Descriptions of the said lubricating cup and vapor trap B.

No. 5. My circular, with the addenda thereto, since attached to the same.

The attention of the committee is also called to the low estimate of cost in performing the entire work, of arranging and putting in place and working order the entire machinery on payment of $100,000, our account, in advance, the company guaranteeing to furnish all additional funds that may be requisite in perfecting the work, and taking all reasonable risks that may be required by your committee.

Attention is also respectfully called to the *small cost of fuel* for operating these machines, not exceeding twenty-five or thirty dollars per diem.

I have the honor to be, very respectfully, your obedient servant,

H. R. DE LAREINTRIE,
President, Sole Agent for the District of Columbia.

Hon. THOMAS A. JENCKES,
Chairman House Committee on Ventilation of the Capitol of the United States, Washington, D. C.

No. 1.

OFFICE OF THE UNITED STATES ICE AND REFRIGERATING COMPANY,
No. 61 *Broadway, New York, May* 9, 1870.

SIR: Agreeably to the request made, on the 28th of April last, on the occasion of my interview with you, I beg to submit herewith the brief memorandum of a plan for cooling and ventilating the two halls of Congress.

I do not propose to enter, here, in the lengthy discussion of trite and obsolete theories on ventilation, nor attempt to demonstrate, by means of elaborate algebraic equations, the possible effect of very abstract causes. The facts which I shall endeavor to set forth before you will be such, only, as will fully stand the test of plain common sense and practical experience.

From such information as I have been able to obtain—and I have taken pains to consult parties both competent and experienced—I have reason to believe that the ventilation of the halls is neither as imperfect nor as deficient as many imagine: the main

difficulty lies, undoubtedly, in the absence of means to properly control the temperature of the rooms, both in summer and winter.

That there is very good, if not wholly sufficient ventilation, is shown by the following fact: the rooms, as is well known, are heated by indirect radiation—that is, by means of hot air from furnaces, supplied through ducts and flues.

No difficulty has ever been experienced, I believe, in maintaining constantly a sufficiently high temperature in the rooms. Now, this could not be done if the ventilation were particularly deficient, and for this reason: if a pipe containing hot water be led to a vessel, closed so as to allow of no egress, when the vessel has been filled so that no more water can enter it, the contents will, in a reasonably short time, cool down to the temperature of the ambient air. In the same manner, when hot air is brought into a room through a flue, unless there be a corresponding outlet, and consequently proper and sufficient circulation, a time must come when no more hot air can gain admission, and the atmosphere of the room, being stationary, must necessarily fall gradually until it approximates that of the outer air.

Disagreeable smells have occasionally been noticed in the halls, and the fact attributed, I think without cause, to deficient ventilation. If a person has been partaking of food seasoned with onions or garlic, or smoking strong tobacco, or drinking alcoholic liquors to excess, the unpleasant odors arising from his person and resulting from these facts will be quite perceptible within a moderate distance, even in the open air, and *a fortiori* in a closed room.

In the matter of temperature, the great difficulty is to suit at once the various temperaments and physical constitutions of the members. Warm and cold are but relative terms, which do not apply equally to every one and, as an illustration, I have heard it stated that the late William P. Fessenden was frequently known to shiver with cold in the same atmosphere which Mr. Hale, of New Hampshire, found oppressively warm.

It frequently happens that members will enter one or the other House at an early hour, to write letters, or for other purposes, and a temperature must be provided in which they may sit comfortably; but it is quite evident that when the hour of meeting has come, the floor has filled with members, and the galleries with spectators, each and every one generating more or less heat, this same temperature becomes almost intolerable.

What, therefore, is absolutely and pressingly needed, is a system by means of which the temperature of both halls may be kept under perfect control, and may be depressed at will, both in winter and summer, with even more rapidity than it can now be raised, whilst, at the same time, securing additional ventilation and a perfectly pure atmosphere.

Such are precisely the results which can be easily attained by means of the "Tellier Air-cooling Apparatus," a drawing of which has been left with your honorable committee by Mr. H. R. de LaReintrie, and a detailed description of the working and construction of which has since been forwarded to you by the same gentleman. I beg to refer you particularly to both of those documents.

The machines are now in successful operation in a number of establishments, both public and private, throughout Europe, among others in the great and well-known brewery of Messrs. Bass & Co., Burton-on-Trent, England, which fact will be found fully stated in Professor F. A. P. Barnard's report on the Paris Exposition, page 393. In this country it has also been introduced in the brewery of Mr. George Merz, New Orleans, where it is giving perfect satisfaction, producing and maintaining with ease *any desired temperature* in a room 50 by 50 and 12 feet high. That these machines are specially adapted to the purpose for which we are now tendering them, is shown by the following passage, quoted from Professor Barnard's report, already mentioned, page 391:

"The ventilation of churches, theaters, and all public assembly rooms during the warm season is another object to which these refrigerating apparatus may be made beneficially subservient. It is now generally true that during the warm days of summer the outer air is at a higher temperature than that within the building; and this will invariably be the case in structures of masonry, provided the windows be kept open during the night and are closed at sunrise. Notwithstanding this, a crowded assembly will find it intolerable, in summer, to sit in an apartment where there is no movement of air. The windows will be thrown open, the warm air admitted, and the assembly will be more uncomfortable than before. Nothing is easier, however, than to introduce into such apartments a steady flow of air at a temperature of refreshing coolness, by which the hot air shall be expelled, and a permanently comfortable atmosphere substituted. To accomplish this desirable object it will not generally be necessary to provide any special system of distribution for the cold air introduced. Our public buildings are in most cases already provided with ducts for conveying heated air in winter from furnaces to their several apartments, and the same channels will serve in summer for air artificially cooled. It will evidently be no less easy to control, by means of registers, the degree of depression of temperature in the apartments than it is, in the opposite season, to regulate the heat."

A glance at the drawing and specifications left with your committee will at once show how specially adapted our machine is to the above-named purposes. Of all ap-

paratus invented to produce artificial cold, it is the only one the construction of which is specially intended for purposes of ventilation and the cooling of air.

In adapting these machines to the ventilation and cooling of the halls of Congress, but few, if any, alterations would be required in the present arrangements of ducts, flues, and registers. These could easily be used to bring in the cold air; ducts of aspiration would, however, have to be established at some point or points near the ceilings, and as far as possible from the orifices of discharge, in order that the cold, fresh air may be compelled to traverse and permeate the entire atmosphere of the halls before finding an outlet. Thus the cold air, driven by the ventilating fan, enters the rooms at a point near the floors; there it meets the warm air, mixes with it, and as it becomes thus rarefied, it rises toward the ceiling, carrying off with it all the impurities or foul gases with which it may come in contact. At this point, the ducts of aspiration, which lead to the chambers of the ventilator, create a constant draught, and thus the warm, impure air is constantly drawn out of the rooms, carried to the ventilator, and again driven through the refrigerating cylinder, where all such impurities and foul gases are cast off in the shape of an abundant condensation, the product of which may be led to any of the existing drains in the building. The chamber of the ventilator shall also be placed in communication with the outer air, by means of a duct or flue, through which a steady stream of fresh atmospheric air shall be constantly brought to the machines; it is immaterial where this air is drawn from, as it is always purified and cooled in passing through the cooling cylinder. By these means, simple and rational in the extreme, it will readily be seen that constant renovation, constant purification, and constant cooling of the atmosphere in the halls will be perfectly and completely secured.

In addition to the various and obvious means of controlling the temperature of the rooms, the action of the machine itself may be regulated at will, by means of an improvement known as a *spring-cock*, which has been added to the apparatus since the drawing was made, of which you have a copy. We have annexed hereto (marked A) a diagram of this ingenious contrivance. Fears have been expressed of leakage of the material used in producing the cold; no apprehension need be felt on that score. Machines of various descriptions are being constantly built in this and other countries, which must be equally secure against leakage as the one of which we are now speaking, and there is no difficulty in obtaining that result. Of these particular machines, Professor Barnard, in his already twice-quoted report, speaks of "the very effectual contrivances for preventing the possibility of the slightest leakage through stop-cocks, joints, or stuffing-boxes." Reference to the drawing and detailed description of our machine will show, conclusively, that there is literally no possibility of leakage at any point, save at the stuffing-box of the pump. To obviate even this bare possibility the inventor has devised a peculiar contrivance, more ingenious still than the "spring-cock," and which serves the double purpose of lubricating the piston-rod of the pump and of intercepting any vapors which might attempt to escape in that direction. We have annexed hereto, marked B, a diagram of this clever piece of mechanism. Finally, and to quote once more from Professor Barnard's report:

"No leakage can take place here, (the stuffing-box of the pump,) as the alkali in the vapors, acting upon the oil of lubrication, would saponify the latter, and thus form an unctuous compound, which, while answering fully the purposes of lubrication, would effectually prevent any escape of gas."

From all that has been said above, it will readily be seen that we propose to ventilate the rooms by means of an *upward* current of air. In adopting this mode of ventilation, we have endeavored, whilst conforming ourselves to the simplest laws of nature, to obtain the greatest possible amount of comfort for the members who are compelled by duty to remain on the floors of the Houses, and have assumed that the comfort of the spectators, who occupy the galleries from motives of amusement or curiosity, was but a secondary consideration. Thus, in our system, the purest and freshest air in the room will always be in that part of the rooms occupied by the members, and their number being relatively very small, no material inconvenience can follow to the spectators above. If, on the contrary, a downward current were adopted, all the effluvia and foul exhalations from the promiscuous crowd in the galleries must necessarily, and despite any possible means of prevention, be swept down upon and to the great inconvenince and discomfort of the members below. Moreover, experience has shown that, although carbonic acid gas is theoretically heavier than atmospheric air, and whatever may be the proportion of that gas in the exhalations from living bodies, the foul air in crowded assemblages always tends to rise, and it is much easier to proceed in accordance with, than in opposition to, its natural tendencies.

In order the better to attain the aim and object of our plan, we would suggest the construction, immediately under the roofs which cover the two Houses of Congress, of ceilings of some neutral material, plaster and laths or simple boards. The roofs are of corrugated metal, and act as powerful conductors of both heat and cold. The construction of the ceilings named above would, under any circumstances, be an improvement on the existing state of things; but we do not make it a part of our plan proper, nor is the

expense of such included in the estimate furnished below. It would be difficult, with the rather limited information at our command, to enter into a minute and detailed estimate of the cost of applying our system to the two halls of Congress. In addition to our machines proper there would be required motive power to the extent of 40 to 50 horse-power for the Senate and 60 to 70 horse-power for the House. The motive power now in use could undoubtedly be made available, at least in part, and it must be remembered that the sole and only additional running expense resulting from the adoption of our plans will be the cost of the fuel required to generate the required power, and this will not exceed \$25 to \$30 per day, even when running constantly, and upon this point we challenge comparison with any other scheme or plan.

Basing ourselves upon such approximate estimates as we have been able to make of the number and size of the machines required, we beg to submit the following proposition: We will undertake to provide both Houses of Congress with such machinery and apparatus, including the required power, fitting up, &c., as will furnish the means of lowering, at any time, the temperature to 70° or 75° Fahrenheit, the atmosphere produced being maintained perfectly pure as well as cool, and the entire expense for both Houses shall not exceed \$300,000, that sum covering all such profit as we hope and expect to realize from the undertaking. Further, if an appropriation of \$100,000 be made for the purpose, we will undertake to execute the work to the entire satisfaction of Congress, spending a like sum and taking all further additional risk ourselves, and no part of the remaining \$200,000 need be paid until the work has been so completed.

We are prepared to commence work at any time, and if placed in position of doing so by or before the 1st of July next, we think we could have it all done by the time Congress next assembles in December next, or very soon thereafter.

All of which is respectfully submitted.

SAMUEL C. REED, *President.*
L. BOUVIER, *Secretary.*

Hon. T. A. JENCKES,
Chairman House Committee on Ventilation.

BALTIMORE, *May* 14, 1870.

The within proposal and estimate is most respectfully submitted to the careful consideration of the honorable the Committee on Ventilation of the two Houses of the Congress of the United States by their very obedient servant,

H. R. DE LAREINTRIE,
Sole Agent for the State of Maryland and the District of Columbia.

Nos. 3 and 4.

Description of drawings A and B.

A. NOTE I.—The float L, at the base of the condensing coil, which is intended to regulate the flow of the liquid back into the cylinder, has been replaced by a "patent spring cock," which effects the same object, whilst permitting, at the same time, the regulating exactly of the pressure in the machine, and consequently to control perfectly its action.

B. NOTE II.—The lubricating cup, which appears on the compressing pump, and which is intended to lubricate the piston-rod of the said pump, is so contrived as to act at the same time as a trap to catch any vapors which might escape in that direction.

As this is the only point where, from the peculiar construction of the machine, there would possibly be any leak, the contrivance effectually removes all such possibility.

Most respectfully submitted.

H. R. DE LAREINTRIE,
Sole Agent for the District of Columbia.

No. 4 *bis.*

Description of lubricating cup and vapor trap, marked B.

The lubricating cup placed upon the piston-rod is cast on the jacket of the pump. Its object is to prevent any leakage of ammonia or methylic ether. It is composed of a piston *a a*, worked by means of a crank B, which forces the oil contained in the cup

e e within the stuffing box D D. The packing of the piston-rod, as plainly shown in the drawing, is in two pieces, E F, divided by a perforated ring, G. It is easy to understand that the oil, pressed by the piston *a a*, caused the valve *s* to drop down, escapes through the orifices *r r*, and is brought by the plunger *n* upon the ring G. Per contra, the vapors which might pass through the packing F rise in the chamber D D, pressing the oil upon the piston-rod, and consequently it is the latter alone which can possibly escape through the packing E. Thus, if care be taken to keep up the supply of oil in the cup, perfect lubrication will be secured, and at the same time absolute protection against leakage. Care should also be taken always to keep the plunger *n' n n* in perfect condition, for the reason that with its assistance it is always oil which rises in *n* up to the valve; whereas otherwise, when the oil would be below the orifices *r r*, it would be gas, and if the valve *s* leaked the piston would act badly, and at the same time vapor would escape through the cup *e e*. Oil may be poured rapidly into the cup until the piston resists under the hand; then it may be certain that it is full. There can never be too much oil, as the consumption is always the same; but lack of oil would be bad. Watch this well, as there only is any chance of leakage. Use castor oil or glycerine.

Most respectfully submitted.

H. R. DE LAREINTRIE,
Sole agent for the District of Columbia

No. 5.

[Circular.]

BALTIMORE AND TEXAS STEAM TRANSPORTATION COMPANY.

Capital stock $200,000.

A joint stock company, chartered and organized* under the laws of Maryland, for the direct transportation of general freight between Baltimore and ports in Texas.

The steamers of this line will be provided with Tellier's (French) refrigerating machine, *guaranteed* by the patentees to keep fresh meats, fruits, &c., in perfect condition, in any climate, by means of cold air—without the use of ice.

The privilege of the exclusive use of this patent, for the transportation of fresh meats, &c., from Texas to Baltimore, their preservation and sale, within the State of Maryland, is vested in the undersigned.

A practical man is ready to superintend the beef business in Texas.

THE TELLIER REFRIGERATING MACHINE

Is the invention of Monsieur Charles Tellier, of Paris, France, a practical machinist of great experience and inventive genius. It has been patented in England, the whole of Europe, and in the United States. It is in actual operation in these countries, and also in the Argentine Republic; has been fully and publicly tested, and found to answer *all* the purposes to which it is applicable, and has produced the results claimed for it by its inventor and patentee. Fresh beef, mutton, and game *have been conveyed* from London to Rio, in the steamer "Rio de Janeiro," expressly fitted out for the purpose with the Tellier Refrigerating Machine, and, after a voyage of *twenty-one days*, were found to be in perfect condition. During said trip, and while on the equator and in its vicinity, the temperature in the refrigerating room was kept at from 32° to 33°, (Fahrenheit,) while outside it ranged from 105° to 107°, and the water itself stood at 80° to 90°.

Beef, which had been *six weeks* in the preserving room, was eaten at the Café Coraza, in Paris, by over forty gentlemen of the most fastidious tastes, who pronounced it of superior quality, delicious flavor, and in a perfect state of preservation.

Game and mutton kept *nine weeks* in Tellier's refrigerating room, in Paris, were eaten at a dinner given to Minister de Lavallette and pronounced in perfect condition. It is proposed to organize a company in Paris,† with a capital of $2,000,000, for the importation of fresh beef from the pampas of the "La Plata" to France, to consist of twelve steamers, each to be provided with the Tellier refrigerating machine. The proprietors of the "Grand Hotel," in Paris, are having one of these machines fitted up for the various requirements of that immense establishment, and which will soon be in running order. It is also in use in many other cities in Europe, and such is the present demand for it, that Mr. Tellier has been compelled to largely increase the area of his manufacturing building (4,100 metres) and the force of his operatives. In New Or-

*Organized May 4, 1870.
† "Société Maritime pour L'importation des Viandes du La Plata."

leans, Louisiana, it has been adopted and set up by Mr. Merz in his large brewery, and has proved a *perfect success.* A company has been organized in the city of New Orleans for the transportation of fresh beef from Texas to that city by means of the Tellier refrigerating machine, and prominent gentlemen of that city, headed by Mr. J. Viosca, jr., have paid the sum of $50,000 of the capital stock of $250,000 into its treasury, and the operations will commence so soon as the machines arrive from France and are fitted up in their steamers.

In the city of New York another company is organizing, having in view the business of introducing fresh beef in that great emporium by means of the Tellier machine.

It is contemplated to organize a company in Paris to transport fresh beef from Hungary and Gallicia to that capital in the Tellier refrigerating railroad cars, provided with this same machine, the power for creating the refrigerating being taken from the car wheel. The outlay is estimated at 450,000 francs, or $90,000 in gold, to furnish, daily, 15,000 kilos (33,000 lbs.) of beef. If the result gives but 10 centimes profit per kilogramme—(about one cent per pound,) a very moderate price—the profit would be for 300 days, say $15,000 \times 10 \times 300 = 450,000$ francs, *or one hundred per cent.*

To fit out a steamer for the transportation of 200 tons of fresh beef from Texas to Baltimore would require, (making full allowance)		$25,000
In addition, a cash capital of, say		15,000
Estimated outlay		40,000
The expenses of a proper steamer of 600 tons, including charter-party, running expenses, insurance, &c., per month	$4,000	
600 head of cattle, at $15 per head	9,000	
Slaughtering and shipping	1,000	
		14,000
Result:		
360,000 pounds beef, at 8 cents	28,800	
600 hides (80 pounds each,) at 10 cents	4,800	
24,000 pounds of tallow, at 10 cents	2,400	
Tongues, horns, feet, &c	600	
		36,600
Net profit *per month*		22,600

Or over 50 per cent. *per month* on $40,000 invested!

This *result* is irrespective of *other freight*, both to and from Texas to Baltimore, which at this day will pay, whenever a steamer is put on this line. The hides and tallow, (fifth quarter,) *alone*, will cover the cost of the beef in Texas, and, when landed in Baltimore, *in perfect condition*, transferred to a refrigerating room on shore, it can readily be sold for *one-half* the present, or future ruling prices. That it can be done, and "will pay," there is no doubt. Should any unforeseen contingency supervene, the margin of profits, *per annum*, is certainly ample.

The Tellier refrigerating machines range from No. 1 to No. 7, cost from $3,000 to $18,000 currency, will cool insulated rooms of from 110 to 4,660 cubic yards capacity, and are *absolutely guaranteed* to produce the degree of cold air required, *without the use of ice*, and at a very trifling expense. Were this not a fact, no man would make, sell, use, or recommend their use.

FREIGHT.

To point out to the intelligent and energetic merchant of Baltimore the many and positive advantages to flow from a direct communication by steamer between our rapidly-expanding city and the ports of Texas is unnecessary. Suffice it to state that such a line is required by the actual wants of the commerce of this metropolis and the oft-repeated wishes of the people of Texas for more immediate and speedy commercial intercourse. The existing trade is, of itself, an ample incentive to the prompt inauguration of this enterprise, and no doubt can be entertained that this commerce only needs development to insure, in the future, its realization on a scale greatly enhanced, through the facilities thus provided.

To the capitalist and business man it holds out a safe and remunerative investment of his means, with no greater risks than those involved in any other enterprise; combining superior commercial facilities with the ports of Texas and the introduction of beef of well-known and acknowledged quality, at prices much below the present, thereby benefiting the people of either State.

Conditions of subscription to the capital stock of $200,000.

1. Two thousand shares at $100 each.
2. Not less than five shares to be subscribed.
3. No installment to be called in until one-half the capital stock is subscribed.

4. Only one installment per month to be paid.

5. Said installment to be ten per cent. of the amount subscribed, by each stockholder.

A portion of the stock to be reserved for the patentees, for the exclusive privilege and use of the patent, by the company, for the transportation of fresh meats, &c., from Texas to Baltimore, their preservation and sale within the State of Maryland—subject to future agreement.

Your attention is invited to the consideration of this great enterprise, respecting which every desirable information will be cheerfully communicated by the undersigned.

Books for subscription to the stock now open at No. 38 Post Office avenue.

H. R. DE LAREINTRIE,
Sole Agent for the State of Maryland, and President of the Company.

BALTIMORE, *March* 17, 1870.

SPECIAL NOTICE.

UNIVERSITY OF MARYLAND, *March* 28, 1870.

SIR: From what I know of the principle and the construction of the "Tellier Refrigerating Machines" and "Ice Machines," and from the results of their actual use in Europe, where they have been thoroughly and severely tested, they will, in my opinion, accomplish all that is claimed for them in your circular.

WILLIAM E. A. AIKEN, M. D., LL. D.,
Professor of Chemistry, &c., &c.

H. R. DE LAREINTRIE, Esq.

ORDERS

solicited for "Tellier's Refrigerating Machines," adapted to the refrigeration required in hotels, breweries, packing-houses, malt-houses, distilleries, fruiteries, dairies, alcoholic and all other establishments which need a cold temperature, which is guaranteed by the "Tellier Refrigerating Machine," without the use of any ice whatever and at nominal cost.

Orders also solicited for "Tellier's Ice Manufacturing Machines," distinct from the first above named. The ice made by this machine is in every respect equal to the natural, and has a greater density than the Boston ice. This has been tested and shown by experiment, at Marseilles.

They will be furnished, on notice of three or four months, on reasonable terms.

H. R. DE LAREINTRIE,
Sole Agent for the State of Maryland and District of Columbia, and President of the Company.

[American, May 4, 1870.]

[By telegraph.]

TELLIER MACHINE—GREAT SUCCESS.

"NEW ORLEANS, *May* 3, 1870.

"Machine working perfectly. Any temperature desired: all are practically convinced.

"F. M. McMILLAN.

"To L. BOUVIER, *New York.*"

And to the truth of which I, on honor, hereby certify.

H. R. DE LAREINTRIE,
Sole Agent.

BALTIMORE, *May* 4, 1870.

[Gazette, May 4, 1870.]

TELLIER MACHINE.

Please insert in your estimable Gazette the following extract of a letter just received from New Orleans, dated May 3, 1870:

"In half an hour we cooled the cellar (Merz's brewery) from 78° to 59° F., and the cooling cylinder was 34°, while the exhaust pipe from cooling cylinder to condenser was so hot one could not bear his hand upon it;" and also that "both myself and all the brewers and engineers of the establishment present were perfectly convinced and satisfied of the success of the refrigerator." McMillan writes, "I can keep this large cellar cold upon one barrel of coal per day. After that I do not think any one need doubt that we can keep the hold of a steamship cold."

To all of which I hereby certify.

H. R. DE LAREINTRIE,
Sole Agent for Maryland and District of Columbia.

A true copy of the original.

H. R. DE LAREINTRIE,
President.

BALTIMORE, *May* 14, 1870.

THOMAS BOYD'S PLAN.

UNITED STATES INTERNAL REVENUE,
ASSESSOR'S OFFICE, FOURTH DISTRICT MASSACHUSETTS,
Boston, April 29, 1870.

DEAR SIR: I am informed that Congress has made, or proposes to make, an appropriation to try some experiments with reference to ventilating the Capitol. This induces me to respectfully ask your attention, and that of those who have this matter in charge, to Mr. Thomas Boyd's Solar System of Ventilation, by means of caps attached to the top of ventilating flues.

My attention was first called to the subject by being on a committee to consider the matter of ventilation for the Home for Little Wanderers. I made many inquiries, and put myself in communication with architects and all persons here whose experience qualified them to give useful information. The consequence was that we procured one of Mr. Boyd's large ventilators which is successful in changing the air in a large school-room with some thirty pupils, a large nursery with twenty to thirty small children, and a large entry on the lower floor, with water-closets and urinals. It combines the advantages of wind ventilators with the heating power derived from the heat of the sun, which is a vey great advantage. My object, however, is simply to invite attention to its merits.

If you can aid Mr. Boyd in gaining a hearing, by those who have this subject in charge, you will greatly oblige him, as well as

Yours, most respectfully,

OTIS CLAPP.

Hon. N. P. BANKS, M. C.

BOSTON, *April* 29 1870.

DEAR SIR: Having noticed that some action has been taken in Congress towards improving the ventilation of the halls in the Capitol, I am desirous of an opportunity to submit a system of ventilation that has proved successful on a large number of buildings here, and is, in my opinion, peculiarly well adapted to be useful there. For this purpose, I have been advised to introduce the subject to you, and respectfully request that you will have the kindness to present it to the gentlemen or committee having the matter in charge, and obtain from them permission for me to furnish a plan for their consideration.

Not having had the good fortune of being personally known to you, some friends have been kind enough to favor me with letters of introduction, one or two of which you will please find inclosed. I also send herewith a small pamphlet, descriptive of my system, explaining the principle on which it acts, and the kind of apparatus I use to procure and maintain ventilation. This will probably be sufficient at present to enable you to understand what I desire to offer.

Trusting that you may deem this of sufficient importance to the Government to excuse me for troubling you with it, I beg to remain,

Very respectfully, your obedient servant,

THOMAS BOYD, *Architect.*
(*Office No. 28 State street, Boston.*)

Hon. N. P. BANKS, M. C.

BOSTON, *May* 3, 1870.

DEAR SIR: Mr. Thomas Boyd, of Cambridgeport, who is well known in this city as a skillful and scientific mechanic and architect, is the inventor and patentee of a Solar System of Ventilation which has been successfully applied to many of our public and private buildings, and is attracting considerable attention among scientific men. I understand from him to-day that he is about to make application to the autherities at Washington with a view to applying his system of ventilation to the Capitol and other public buildings there, and desires to secure, if possible, the attention of any committee of Congress having in charge the important matter in which he is interested.

Mr. Boyd has shown to me letters addressed to you in his behalf by the Hon. Isaac Livermore, Mr. Otis Clapp, and other gentlemen, certifying to his character and standing in this community, and asking your kind offices in his behalf, which it gives me great pleasure heartily to indorse. I have known him personally and professionally for many years, have seen his solar ventilators successfully tested, and have the utmost confidence in their practical utility.

Any aid you can render to Mr. Boyd, consistent with your many official engagements, to enable him to obtain a hearing, will be highly appreciated, not only by himself personally, but by his many friends in Boston and vicinity, and greatly oblige

Yours, very truly,

N. A. THOMPSON.

Hon. NATH'L P. BANKS,
Washington, D. C.

OFFICE OF THE HUNTOON GOVERNOR FOR STATIONARY AND MARINE ENGINES AND WATER POWER,
Boston, May 10, 1870.

SIR: We are led to address you, on our return from a recent visit to the capital, during which time we attached, by order of the Department, two of our improved governors to the engines at the United States navy yard. If we are correctly informed, an arrangement by which a more uniform temperature could be maintained in chambers of the United States Senate and hall of Representatives would be met with favor by your committee.

We feel confident that in no way could this end be accomplished more completely than by maintaining in the engines employed for this purpose a perfectly regular and unvarying speed. We therefore very respectfully submit for your consideration the following proposition, which after our large experience in such matters we feel justified in making, thus:

With your permission we will attach to the engines of the heating apparatus of the United States Senate, our improved governors, entirely at our own expense, and without hinderance to the running of engines, awaiting, after a practical trial of the same, your acceptance or rejection. If pronounced sufficiently valuable, the entire cost to the Government will be $200 for each engine. If otherwise, we will remove them, leaving the engines exactly as at present, with no charge whatever.

Very respectfully, awaiting response at your convenience, I am your obedient servant.

J. AUGUSTUS LYNCH,
Treasurer, Proprietors Huntoon Governor.

Hon. THOMAS A. JENCKES,
Chairman Committee on Ventilation, &c., Washington, D. C.

It has been proved conclusively, after long practical trial, (the severest tests being hourly brought to bear,) that by the employment of the Huntoon governor the engine to which it is attached will run without any variation whatever in the speed, whether heavily loaded or running light, and wholly uninfluenced by the varying pressure of the steam.

The centrifugal or ball principle being entirely abandoned, the valve-lever is sustained as easily at one point as at another, by the action of the propeller in the oil cylinder; and from this fact, together with others peculiar to its construction, we are thus enabled to guarantee a direct saving of fuel, or greatly increase the power of the engine.

The ease and quickness with which it can be adjusted, to cause the engine to run either faster or slower, by simply changing the position of the weight on the lever, has been deemed in many establishments of much importance; which will enable the hot blast to be varied to accommodate the variableness of the external temperature.

Our pulleys which accompany each machine are so constructed as to insure great safety from accident to the governor belt, but where it is desired we attach a new device by which the instant any such accident should occur the engine is brought gradually to a stand-still.

Engine-builders and others who have investigated the principle and mechanism of the Huntoon governor, in recommending its use, have convinced their patrons that it possesses decided advantages over any ball or centrifugal device, and a sure proof of its economy in the use of steam commends it to the users of power generally.

Although its reliability is now proved beyond a doubt, on hundreds of engines where other forms of governors have failed, yet, if requested, we are perfectly willing to allow time for trial, and if in any instance its operation is not entirely satisfactory to our customers we shall not consider it a sale, and on its return we will pay all charges of transportation. However violent or sudden may be the changes, we warrant it to absolutely govern the engine.

It is a great favorite, from the fact of its compactness; it is noiseless, and from its peculiar construction requires but little care from the engineer, every bearing being of necessity lubricated.

References furnished from those now using them, in all branches of manufacturing business.

R. K. HUNTOON,
J. AUGUSTUS LYNCH,
Proprietors, 103 *State street, Boston, Massachusetts.*

SUGGESTIONS OF STEPHEN CULVER.

NEWARK, WAYNE COUNTY, NEW YORK,
May 13, 1870.

SIR: Yours of the 7th of April last, in reply to mine of a previous date, stating that any communication on the subject of the better warming and ventilation of the congressional halls would be considered, was duly received. Other engagements have prevented my writing earlier.

In this communication I intend to make only a few general observations relative to fundamental principles involved in warming and ventilating large buildings of the character of the congressional halls, reserving for a future paper matters of detail.

It may be borne in mind that in what I shall have to say I shall speak of the process of *warming* as a different one from that of *ventilation*. In other words, shall not use the term "ventilation" in such sense as to be expressive of the warming of an apartment, since the temperature of the air of an apartment may be raised to a degree which shall be genial, while at the same time it may be greatly vitiated. And, on the contrary, the air of a room may be pure and healthful, and at the same time of too low or too high a temperature to be comfortable. By *warming*, I shall mean the raising and keeping the temperature of the air of an apartment at a degree that would be genial to the occupant; and by *ventilation*, the continuous changing of the air of an apartment by the removal of that which is vitiated from within, and the replacement of it by that which is pure from without.

Because the warming and ventilation of the English houses of Parliament were rendered better than before by the delivery of air at the upper portion of the rooms, many theorists and some practical engineers in this country advocate that system as the very best, while, in fact, it is not, the result in the case referred to being only an instance in which natural laws are opposed, and, to a limited extent, successfully overcome, thereby accomplishing a desired end much less perfectly and at much greater expense than might have been done by another method.

The delivery of air-currents into large halls at the top involves great expenditure for power to move and for conductors to convey them to the apertures of delivery; and when done, that only has been accomplished which could have been effected more perfectly and at much less expense by proper apparatus and delivery at the bottom. When air-currents are delivered at the top, and a corresponding quantity of air is removed from the bottom—the only proper place for removal—the general current in the apartment is as strong as in the case of the delivery at the bottom, for the reason that if, in connection with and as a part of each method, the air be withdrawn from the bottom, an equal quantity in each case would in equal times be moved to the apertures of discharge.

If air-currents be admitted at the bottom of an apartment they at once rise to the upper and highest portion of it—to the very place to which they are conveyed by costly appliances by the method called "downward ventilation." Besides, if the vitiated air be withdrawn from the bottom of the apartment the currents of replacing air will readily, naturally, and in sufficient quantities, flow into it; and if properly admitted and distributed, are unfelt and unperceived.

One of the principal causes of failure in the endeavor to warm and ventilate large spaces is, that the attempt is made to accomplish the object through the agency of a much too limited supply of air, the practice being to depend upon a comparatively small quantity raised to a comparatively high temperature. The quantity employed should be very much larger than is usually provided, and should not be raised higher than the temperature of surfaces heated by steam of pressure not exceeding 10 pounds to the inch.

Another difficulty encountered is, that by the usual process of heating, the air delivered to the apartments has an odor imparted to it, and also a quality which produces an unpleasant sensation when respired. These conditions are caused by the faulty construction of the heating surfaces by which the air-currents are detained in contact with them too long a time. The contour of all heating surfaces should be such as to permit the impinging currents to leave freely and without detention; and all air-chambers and conductors for the supply of air should be so constructed as to afford a speedy passage, without compression or obstacle to retard.

The proper method, therefore, for warming and ventilating large spaces, such as the congressional halls, is, to deliver at the bottom of them, in sufficiently large quantities, at proper localities, through properly constructed diffusers, air warmed by surfaces heated by steam of low pressure, and the withdrawal of equally large quantities from the bottom of the apartments through sufficiently numerous and properly constructed and located exhaust-orifices, the withdrawal being effected by mechanism actuated by a properly adapted steam-engine; no apparatus except a suitable system of conduits, and no extraneous mechanical power being required for the delivery of the air *to* the apartments.

An opinion has been expressed, as stated in some of the public journals, that there

could be no efficient ventilation of these halls without the removal of the lobbies. Such, however, is not the fact, for, by proper appliances, all parts of the halls could be well ventilated without such removal. By the employment of apparatus commensurate and properly applied, any large space, however irregular in form, can be as well warmed and ventilated as a small one.

Should the committee desire suggestions relative to any particular points, I should, at any time, be pleased to furnish them.

Very respectfully,

STEPHEN CULVER.

Hon. THOMAS A. JENCKES.

PROPOSITION OF WILLIAM WHEELER HUBBELL.

To the Committee on Ventilation of the House of Representatives:

Referring to my proposition submitted, I now say that I have examined the existing construction for ventilation and heating, &c., and do not propose to alter or impair any of it; but can adapt the principles of my invention or system to the existing constructions, to answer every purpose. I therefore propose—

1. To let cold water flow through the steam-heating pipes in summer and use them for steam, as heretofore, in winter.
2. To throw a large fine cold water spray, with double supply head, at the air-supply mouths to the existing blowers on the outside of the building, arranged as I will direct.
3. To let the engineers have a supply register from the hall blower, and run it at speed for this addition, arranged as I will direct.
4. To place the escapements on the roof, constructed and arranged as I will direct.
5. For winter use, to moisten the air, I use a steam spray near the steam-pipes to heat and to insure proper moisture; in very hot weather I admit a very fine steam spray discharge at the eye of the blowers; very little steam will do in summer, just to properly moisten the air without heating it.

I will put in these improvements for the sum named in my former communication, and will give specific details of sizes, forms, construction, &c., as required.

6. There should be a ventilating column with proper ornaments, &c., to suit general appearance of the Capitol—provided, after the other work is put in and in operation, I shall find that its proximity to the supply-mouth will not affect the temperature or quality of air at that point. The cost would be about $3,000 additional, properly constructed. It may not be essential or material to place it there, and hence I do not propose now to add it. The registers I shall put in will dispel some of that heat, and possibly be all-sufficient.

Respectfully,

WM. WHEELER HUBBELL,
340 Pennsylvania Avenue.

PLAN OF WILLIAM WHEELER HUBBELL TO VENTILATE THE HOUSE OF REPRESENTATIVES.

To the House of Representatives, or Committee on Ventilation United States Capitol:

Place five escapes on the glass roofing, covered thus, made of sheet-iron:

TO SUPPLY FRESH AIR.

Make a cold-air connection with the supply-furnace pipes, and use a fine jet of steam to accelerate and moisten the supply in hot, dry weather, with a waste pipe or opening to let off the condensation, and admit the fresh air into the House through the registers, that it may be disseminated without too much current at any one place. Have proper cut-offs so that the arrangement may be used both in winter and summer, for both heating and cooling the House.

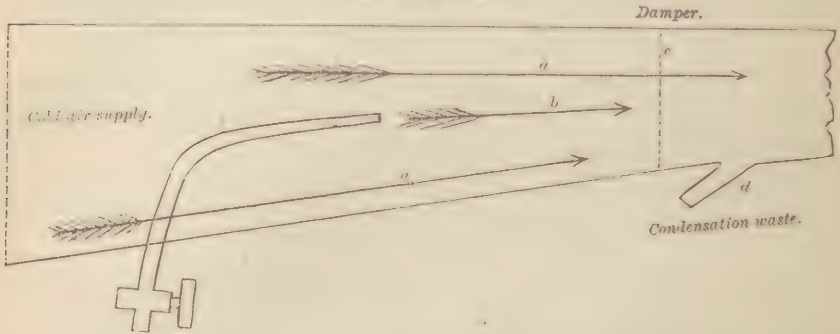
I will put in this arrangement so that it shall answer the purpose for $12,000.

To conform to the action of the House already had, I will put in the arrangement with the experimental fund appropriated, and if the House is satisfied with it the balance of the $12,000 shall be paid to me, and if not satisfied with it then nothing more need be paid to me for it.

WM. WHEELER HUBBELL,
Inventor and Scientific Engineer, Philadelphia, Pennsylvania.

WASHINGTON, D. C., 340 *Pennsylvania Avenue, May* 14, 1870.

PLAN OF SUPPLY.



a a, Arrows indicating course of air-supply to register-pipes; *b*, coinciding steam-jet one-quarter inch; *c*, damper; *d*, condensation waste; *e*, steam-jet supply-pipe to moisten the air and accelerate the supply.

WM. WHEELER HUBBELL.

MAY 14, 1870.

PROPOSITION OF R. H. ATWELL.

23 COURTLAND STREET, *Baltimore, June* 11, 1870.

SIR: I am informed by a member of your House that your committee (on ventilation) receive propositions for plans of ventilation applicable to the auditorium and give them a respectful consideration. I will, with your leave, give a very brief statement of my plan involving the use of power. If it should prove to be at all worth while I will elaborate it, giving the means of filtration, moistening, measuring the moisture automatically either before or after warming, and of distributing through the hall, and if necessary, I think I can determine automatically the absence of the normal quantity of oxygen.

As to the mechanical portion, I beg to say in explanation that my present impression is that the air should be taken from the top of the dome through a pipe, probably tinned, and distributed in the hall by means of iron pipes—gas pipes—attached to every angle of the ceiling, as along the cornices and around supports of the glazing, in such manner as that they shall not mar any beauty, nor indeed be visible but on close examination; these should be perforated every inch or two, the holes being about the twelfth of an inch; the introduction, if practicable, at the center of the ceiling, with, as regards delivery, compensatory arrangement for friction in pipes, &c. The rationale is thus: the higher portion of the room where the pipes would be distributed being, or made to be, without openings, such as are frequently made for ventilation; the air introduced being distributed by means of these perforated pipes would with the proper pressure fill the space and produce a mass movement downward without exciting what is called a "draught" or current in any direction, except out, at the doors or crevices or windows, at will. This is strictly in accordance with natural laws. The force the animal

exerts in expiration is always downward, and a pause always succeeds it sufficiently long for the carbonic acid to pass away and cool before an inspiration succeeds, as you are aware carbonic acid, which is chiefly to be regarded in the matter, is of considerably greater specific gravity than atmospheric air and should always be expelled downward. It may be questioned whether it ever reaches the ceiling in your hall, but it probably becomes cooled a few feet above your heads, and is precipitated upon you and inhaled again with all its added horrors of uncleanliness and disease.

This plan would possess the advantage of not being very expensive, though this should be no consideration if a better plan can be carried out at greater expense.

Yours, truly,

R. H. ATWELL.

Hon. T. A. JENCKES, *Washington*.

PLAN OF WILLIAM LOUGHRIDGE.

BALTIMORE, *June* 11, 1870.

DEAR SIR: Some time since my attention was drawn by a newspaper paragraph to an effort on the part of Congress to improve the ventilation of the House of Representatives. I wrote my friend Hon. Wm. Loughridge, of Iowa, who told me that he had spoken to you as chairman of the committee having the subject in charge, and that you had kindly promised to give me an impartial hearing.

I received from Mr. Loughridge, last week, a notice that you were approaching your report, and I answered him I would send in my plan this week; I have found it impossible to do so before next Wednesday. If that will be in time I will forward my plan; if not, I beg of you not to delay your report on my account.

I think that it is entirely feasible to give entire satisfaction on that subject, but as the ablest minds in the world have failed so often, I may be mistaken. It is simply a question of enough pure air to each member of your honorable body, without respiring it, or part of it, a second time. I think the present means to force the air is sufficient and that no very expensive alteration need be made to accomplish the work.

Respectfully, yours,

WM. LOUGHRIDGE.

Hon. THOS. A. JENCKES, *Washington, D. C.*

BALTIMORE, *June* 28, 1870.

DEAR SIR: I went to Washington on yesterday, and found your favor notifying me of your return home, when I got back.

I left with Hon. Wm. Loughridge a rough drawing and specification, giving the outlines of my plan.

It was hastily gotten up, but I believe the essential points necessary to a perfect ventilation are in it. I was in the galleries for about one hour, and from the free exercise of fans, &c., I saw plainly that the ventilation in the hall below was far from satisfactory. I also observed a material change in the atmosphere from 10 to 11 o'clock, before the hall was occupied, until 11 to 12, after it was occupied. I also observed yesterday (but could not last week from the point I stood, the galleries being full, and I was never in the hall or galleries before) that there was more register surface than I expected, and that there was more egress at the ceiling than I expected to find.

To effect a perfect ventilation the force that sucks or creates a vacuum above the ceiling must be nicely adjusted so as to attract all the impure air from the hall. Evidently as the air enters the hall, as it becomes rarefied, it expands, therefore the area for egress must excel the area of aperture for the ingress of the air, or the suction force must be greater so as to give in velocity of the air what it lacks in apertures of escape.

I am strongly impressed with the necessity and great utility of using the desks or parts of the desk for registers. I can increase the register surface at each desk at least 20 feet; this would increase the present register surface to at least 4,000 feet; as a consequence a much greater quantity of air can be forced into the hall with a much less average velocity, thus obviating the serious objection to a draught.

It seems to me if one row of desks were equipped in the manner I suggest, that a fair sample of my plan could be observed. I do not think any man living can exactly foresee the result of any mode, but I think that a little experiment would insure ultimate success.

I believe the present hall can be made to give entire satisfaction at a less cost than my former estimate.

I take the liberty of clipping the inclosed editorial.

Yours, truly,

WM. LOUGHRIDGE.

Hon. T. A. JENCKES, *Washington, D. C.*

BALTIMORE, *June* 23, 1870.

SIR: In answer to your favor of 20th instant, I respectfully submit the following plan for a more perfect ventilation of the hall of the House of Representatives. I wish this to be regarded as the outline or leading principle of my plan, subject to alteration and modification, so as to be adapted to the present construction of the hall. I believe the change can be made at a less cost than $75,000, and when completed that it will give entire satisfaction in supplying to each member of your honorable body an abundance of air from the present point of supply, attempered, during all seasons of the year, to any degree Fahrenheit.

I do not propose theorizing upon the philosophy of ventilation, the component parts of air before and after respiration, the cubic feet each person requires per minute, the advantages of an upward or downward movement of the air, &c., as these are after considerations, and able articles, (arrived at by experiment,) may be found in the "New American Cyclopedia," vol. 16, page 208, and elsewhere. I simply propose a plan that, in my opinion, is adapted to the hall of the House of Representatives *as now constructed;* and that will at all times, regardless of all contingencies common to ventilation, supply to each person within the hall a sufficiency of air, capable of being increased or diminished at the will of the engineer for the hall, or of each member at his own desk, without interfering with the comfort of other members.

The nature of my invention consists—

Firstly. In distributing the air which may enter the hall in *equal proportions at each desk*, and at other points where respiration takes place, *and at a low velocity through large areas so as to prevent a draught.*

Secondly. In conveying all impure air after respiration, &c., upwardly, through a perforated ceiling of glass, or other material, in nearly perpendicular lines from the point of respiration, by creating a vacuum beyond the points of egress by suction fans, or other artificial devices, so as to regulate the upward velocity of the air from the point of ingress (near the floor) to the point of egress, (at the ceiling,) so that it shall rise at all parts of the hall in a body and move at any *graduated* velocity in feet per minute, and that the line between the pure and impure air shall at all times be nearly parallel with the surface of the floor.

Thirdly. In deflectors arranged under the desks, with universal joints, to enable each member to conveniently deflect the draught upon the floor, or upon or from his person, or in any other direction at his pleasure.

I regard the present hall of the House of Representatives as well suited for my mode, and the present steam-engines, fans, &c., as, perhaps, of sufficient power for the work. I am of the opinion, however, that the present locality from which the air is drawn to supply the hall is objectionable. At times the air is impregnated with a malarious poison arising from the Potomac, and the decomposition of animal and vegetable matter around the city. I incline to the opinion that a much purer atmosphere would be obtained by running pipes some distance northeastwardly into the country, to a point where a reliable water-power could be had to force pure air into the public buildings, at much less cost than with steam engines as a motor.

The gist of my plan is, to supply equal quantities of air to equal areas of surface within the hall, and as nearly as possible in imitation of the open atmosphere. Any system that will not deliver to each person his proportion of all the air forced within the hall must fail to give general satisfaction.

Air, like "Benton's buffalo," or projectiles, follows straight lines, unless diverted from its course, and the greater quantities flow to the larger apertures; therefore, the apertures admitting the air, as well as those giving it egress, should have areas in proportion to the pressure of the air at all points, so as to equalize the inflow and outflow of the air into and out from the hall at every point.

Air is subject to the laws of gravity, force, resistance, inertia, and momentum; but there is no natural law that induces it to search through large audiences for the purpose of administering oxygen to those in want of it; therefore, with the present plans of construction, with but few openings to admit air into public halls, the air is carried at *high velocities* beyond the point of respiration, and the greater proportion of it is not utilized proportionately by the audience.

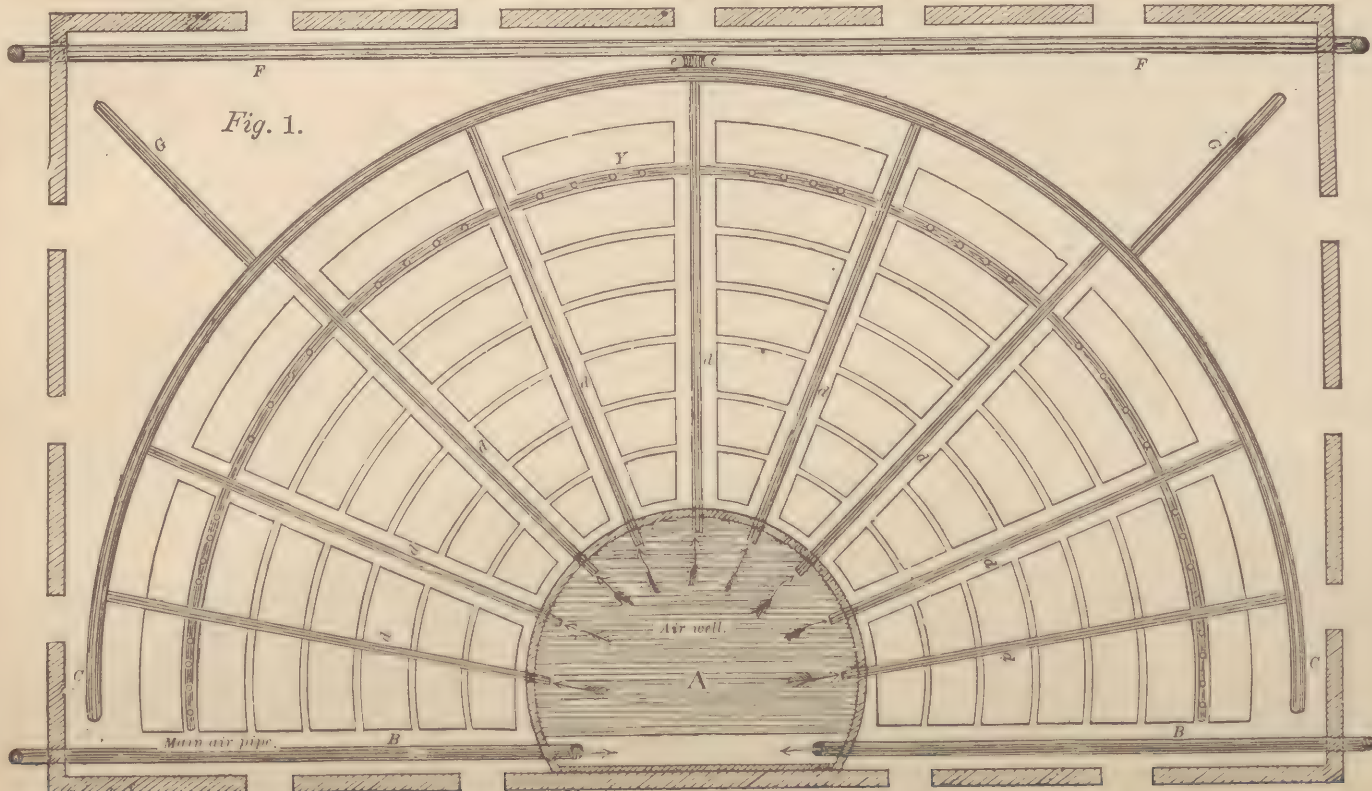
For plan and specification see annexed paper B.

Yours, very respectfully,

WM. LOUGHRIDGE.

Hon. T. A. JENCKES, *Washington, D. C.*

WILLIAM LOUGHRIDGE'S PLAN FOR VENTILATING THE HALL OF THE HOUSE OF REPRESENTATIVES.



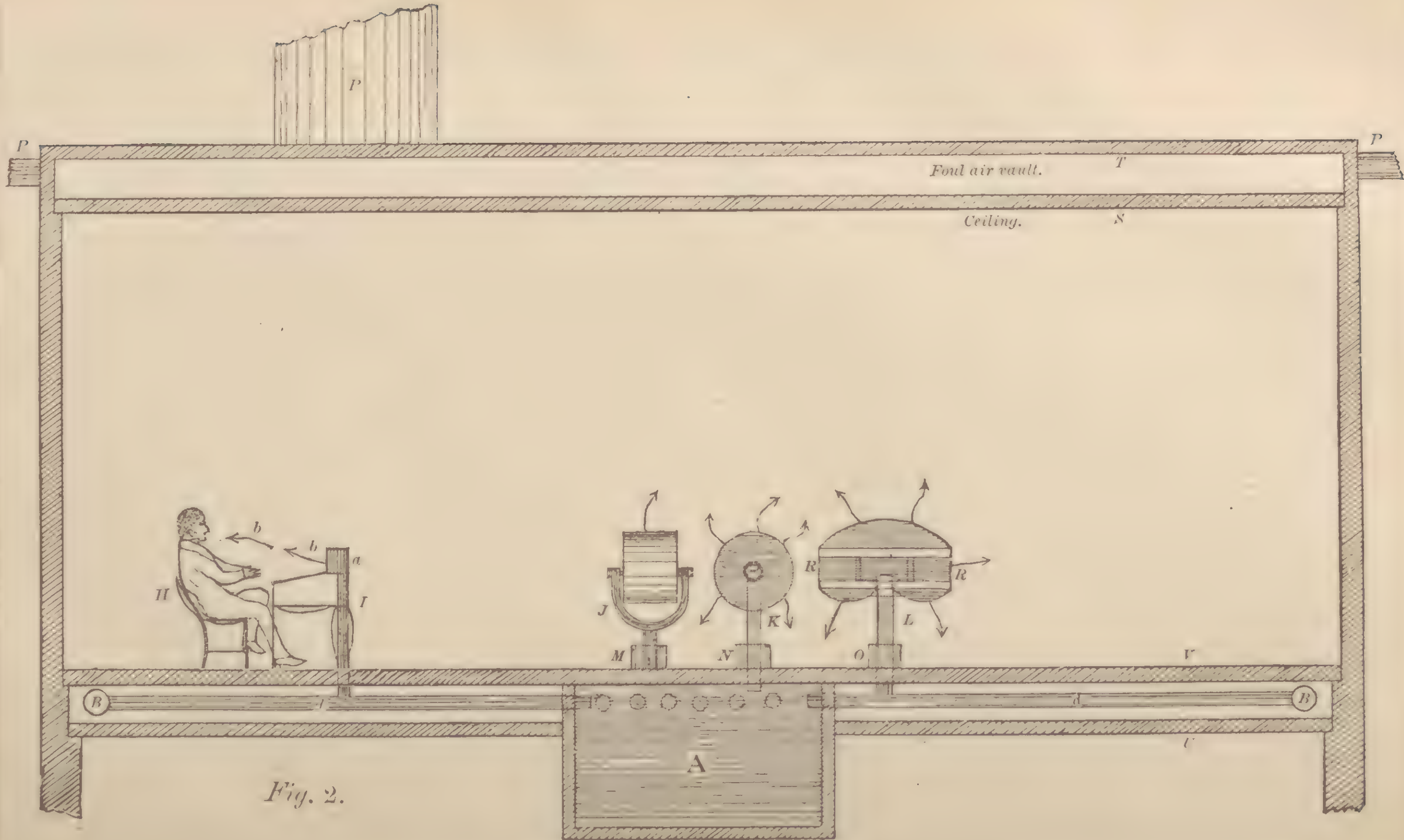


Fig. 2.

B.

A specification for a plan by William Loughridge, of Baltimore, Maryland, for ventilating the hall of the House of Representatives.

Fig. 1 shows the floor of the hall, with the honorable Speaker's chair omitted. Fig. 2 is a side elevation, showing one honorable member of the House seated at his desk. This figure may be considered as a representation of each member in his respective place, excepting that it is not on a true (too large) proportionate scale. A represents an air-well between the two floors, U V, (see side view,) immediately in front of and under the Speaker's chair. This well would be better if carried to a depth of 20 or 30 feet, so that a large body of air may be accumulated within it: and also for the purpose of attempering the air by heat or cold to any desired degree Fahrenheit. B B and F F are four main arteries, or feeding-pipes, that convey the air from the fans or force-pumps into the air-well A. C is also a large secondary feeding-pipe, that is connected (Siamesed) with F at c. G G are two branch pipes that connect with C, and may run into and out from registers in any part of the hall. Any of the other pipes may also run into and out from registers, so as to afford the same, or more, register surface than is now constructed within the hall. The one end of the pipes pass through the shell of the air-well A; thence through the aisles, with the other ends, into the semi-circular pipe C, affording a free circulation and communication of air from the fan to the well, or from the well to all the conduits or pipes belonging to the whole system. Y represents small air-pipes, that connect at each end with the pipes *d* under each tier or semi-circle of desks. These small arteries complete the whole system, and I aim to induce a free circulation of air through all parts of the pipes, with a pressure or tendency of the air to escape into the hall with equal force and in equal quantities at each desk. If, however, owing to the friction of the air, or other causes, the escape into the hall should not be equal to the quantities desired at each point, then by regulating the size of the escape apertures the desired quantities may be obtained.

One of the sockets M N O is intended to be screwed into the pipes Y at each desk, and all other points where air is to be admitted into the hall. These sockets may be cut off flush with the floor, recessed below the surface, or as they now show in the drawing. Within these sockets valves may be constructed, ground air-tight, to bear upwardly against the lower ends of the sockets, and held there by springs until pressed open, as hereafter set forth. I represents one of the desks with an air-chamber *a*. I propose making one or more of the legs of each desk, seat, or lounge hollow, so that the air can pass from the supply chamber into any air-chamber that may be constructed upon, within, under, or about the desk. I also lengthen the hollow legs of each desk, which may be set into the socket M and C, so that the valves in the socket M will be forced open, and the air have free circulation from the air well to the reservoirs in the desks, &c. The angle of the reservoir *a* may be so adjusted that the air will flow in direct lines from the reservoir to the respiratory organs of each member, as shown by the arrows *b b*, or in any other direction at will. I also propose regulating the inflow of air at each desk, or other points, by cocks or valves, to meet the wishes of each member.

"In man the respirations are generally thirty-five per minute in the first year of life, twenty-five during the second, twenty at puberty, and eighteen in the adult age;" therefore different persons, at different periods, require different quantities.

The figures J, K, and L show different ways of securing a large area of canvas, silk, or other material, which can be thrown over registers to allow the air to permeate into the room at a low velocity. With these canvas registers put over apertures on the backs of the seats, in different parts of the desks, or furniture of the hall or galleries, will afford plenty of pure air without the least perceptible draft, as the surface can be made ample for the lowest velocity of air. I propose cutting apertures in the ceiling, so that the foul air shall pass into the foul-air vault T; and from this vault I extend pipe or pipes P to some desirable point of exit, as set forth in paper A.

Having in an imperfect manner set forth the leading points of my mode of ventilating the hall of the House of Representatives, I may send some other papers more explanatory of the whole plan. I shall not annoy you, however, with persistent and prolonged effort to induce its adoption; but will be pleased at all times to make further explanations, and, with the assistance of your able architect, make any experiments on a small scale to demonstrate the truth of the whole. With this plan the profile of the floor can be maintained as it is at present, and there will be but slight alteration required at any point. Of course all the pipes shown in the ground-plan will be covered, and if the legs of the desks are availed of to convey and distribute the air around each member, the change will hardly be perceptible; but that the result will be as near perfect, or lead to perfection, I have not a single doubt.

I present this plan to your honorable committee and to the honorable Congress of the United States with a hope that I shall have your coöperation.

Very respectfully, yours,

WM. LOUGHRIDGE.

SUGGESTIONS OF ROBERT BOYD.

EVANSVILLE, *January* 2, 1871.

DEAR SIR: By this day's mail I forward you some pamphlets on an economical system of ventilation, on which I received a patent in November, 1867, and have used it with very satisfactory results. Being anxious to bring it into more general use, I recently visited New York and Massachusetts, (from whence I have just returned,) and exhibited my model to several scientific gentlemen, architects, builders, and others of high reputation, and it received their hearty and universal approbation. Having met with this encouragement, I have been induced to present it still further, and through the kindness of my esteemed friend Hon. John C. Shoemaker, (whose letter please find inclosed,) I take the liberty, most respectfully, to ask you to do me the favor to bring my system of ventilation to the attention of the congressional committee on that subject. I could furnish you many testimonials in favor of this system and its construction; but I prefer to present it on its own merits, believing the gentlemen that are on that committee to be fully capable of judging its merits, and deciding whether it is worthy of their approval and recommendation or not.

For a moderate sized room, one of these ventilators is sufficient; for large rooms, as many may be used as will be necessary for thorough ventilation. I make a slight difference in their construction for hospitals from those used in other places, but no difference in the plan or system. Simplicity, economy, and utility are its chief points.

If the honorable committee should give it a favorable consideration, and require any further explanations in regard to it, I will be glad and happy to respond to their call at any time.

I am, very respectfully, yours, &c.,

ROBERT BOYD.

Hon. WM. E. NIBLACK, *Washington City*.

The inclosed letter of Robert Boyd, esq., with accompanying pamphlet on ventilation, is respectfully referred to Hon. Thomas A. Jenckes, chairman of the Committee on Ventilation of the House of Representatives.

W. E. NIBLACK.

WASHINGTON, D. C., *January* 9, 1871.

(This proposition refers to a pamphlet containing a description of an apparatus patented by Mr. Boyd, but there was no proposition to adapt it to either hall. As any attempt to use it would require considerable alterations and a new and expensive apparatus, the committee did not prosecute their inquiries in this direction any further.)

MEMORIAL OF A. J. MARSHALL, ON THE VENTILATION OF THE TWO HALLS OF CONGRESS.

To the Senate and House of Representatives of the United States:

The memorial of A. J. Marshall, a citizen of the State of Virginia, respectfully represents, that he has for many years made the art and science of ventilation the subject of his earnest thought and most labored investigation; and he confidently affirms that he has invented improvements upon existing plans or systems, as practiced here and in Europe, which will advance the art of ventilation to a stage of excellence not heretofore attained.

Your memorialist claims, in an especial manner, to have studied the character and philosophy of the system on which the two halls of Congress have been ventilated. He has no criticism of his own to offer, but will refer to the luminous and comprehensive reports of joint committees of Congress, made within a few months past, on the ventilation of the Capitol. In those reports will be found an able exposition of the deficiencies and inherent vices of the ventilation now given your legislative halls.

From these elaborate reports the mortifying fact is gathered, that a system of ventilation has been imposed upon the two Houses of Congress, from the errors and vices of which the legislative halls of Great Britain and France, after costly struggles between opposing systems, continued through a score of years, have just been emancipated. Thus it appears that a hurtful and erroneous system of ventilation, a system exploded and abandoned because of its wrong philosophy and practical inefficiency by the most enlightened nations of Europe, has been adopted here, and in face of this warning experience has been foisted upon the two halls of Congress.

Nor is the adoption of the discarded systems of the Old World the only blunder bearing on a good ventilation which these able committees have exposed and disclosed for correction and amendment. Their reports demonstrate that the evils of this exploded system of ventilation have been greatly aggravated and multiplied by the ex-

periment of lighting these spacious halls through an immense glass dome placed in the roof, and expansive glass ceilings placed over each, thereby subjecting the halls to the influence of a direct solar action upon and through this vast area of exposed surface.

The conclusion to which these committees come, after most thorough and searching scrutiny, is that the two halls of Congress can never be properly ventilated, unless the structure of the halls is altered in conformity with the original plans of the architect, and unless the present obsolete plan of ventilation now in use at the Capitol shall be abandoned, and the modern ventilation, sanctioned by the experience of England and France, shall be substituted therefor.

In this judgment of your committee the memorialist entirely concurs; but he must be permitted to state that this modern plan of ventilation, although a great improvement upon the ventilation now furnished in your halls, is itself, in some important respects, defective and inefficient. It is therefore matter of gravest interest that remedies for these imperfections shall be discovered and applied.

Your memorialist claims to have discovered such remedies, and by a new arrangement and combination, and by novel and simple devices, he claims to have invented a new plan or method that will improve and perfect the proposed ventilation, and secure within the halls of Congress a pleasant and wholesome ventilation, adapted to all the changes of our variable climate.

Your memorialist, in anticipation of the action of Congress on this interesting subject, had prepared papers explanatory of his invention, which he had designed to submit to a committee, if one should be appointed. He begs leave to incorporate these papers (as Appendix A and B) to be taken as part of this memorial. They disclose, as far as it is proper to be explained in a memorial, the nature and principles of the invention.

Your memorialist respectfully asks that his petition may be referred to a committee, with instructions to investigate the subject, and report what action in the premises will best subserve the public interest.

Your memorialist will ever pray, &c.

A. J. MARSHALL,
Warrenton, Virginia.

APPENDIX A.

To the Honorable Chairman, &c.:

GENTLEMEN: I ask your attention to a subject of grave importance, to wit: the wholesome ventilation of your legislative halls. It is conceded on all hands that the existing plan of warming and ventilating these halls has proved to be an utter failure, from the evils of which our national legislature must be rescued.

A careful study of the vices and inefficiencies of this ventilation at the Capitol, and, indeed, of all the plans or systems of ventilation hitherto practiced upon, in Europe as well as in the United States, has suggested to my mind remedial devices, that will improve and largely advance the science of ventilation, and relieve it from this opprobrium of inefficiency.

These devices constitute a "new method" of ventilation, which I have recently caveated, and to which I now ask your attention. As applications for foreign patents are yet depending, it is inexpedient to make full explanations of the peculiar devices of this new method, except to the committee in the confidence of consultation. I propose, however, in this paper to foreshadow some of the leading and novel results of the new system.

First. The air for ventilation will be drawn from a point of great altitude—a point high above the region of the local miasmas of the city or of the Potomac, and beyond the range of the warmth that radiates from the earth's surface. Thus will be secured for respiration in the halls an atmosphere of absolute purity, which will also, in summer heat, be very much cooler than will be the lower strata of air.

Second. This pure air will be attempered and prepared for the halls by simple devices, and in a manner more manageable and convenient than at present. It will then be sifted in at the ceiling, in accordance with the original design of the Architect of the Capitol Extension, and in conformity with the received systems of ventilation now prevalent in Europe.

Third. By a novel device of marvelous simplicity this ventilating air will be forcibly detained and accumulated within the halls until it has attained a compression or condensation therein of, say, five or ten pounds the square foot, (not the square inch!) or of any degree of pressure that experiment may prove to be best and most sanatory. At such point of condensation the condensing device will yield to the pressure, and the foul air will be forced to escape through the then open registers on the floors of the halls and the risers of the galleries.

It is to the greater purity of the ventilating air, and in this novel feature of meas-

ured condensation in the halls, that the greater excellence of the new method of ventilation may be mainly attributed. The great benefits of a pure air in ventilation will need no illustration; but the admirable results achieved by this novel feature of condensation are not so apparent, and therefore I propose to make a succinct enumeration.

The first result of a measured and regulated compression of air within the halls will be very much to improve their acoustic capacities. The voice of the speaker, in its every intonation, without increased strain on his lungs, will be heard at every point of the halls and galleries: for it is a well-established truth that the more dense the medium, the more perfect always will be the transmission of sound. In addition to this effect, it is verified by eminent physiologists and physicians that condensed air has a tendency to brace the nerves, improve the digestion, and in a measure to energize the mental functions.

A few years since, the cheering and bracing effects of condensation upon the human system formed the subject of a series of interesting physiological experiments made by a Mr. James, who thus writes:

"When a person is placed in condensed air, he breathes with a new facility. He feels as if the capacity of his lungs was enlarged. His respirations become deeper and less frequent. He experiences in a short time an agreeable glow in his chest, as if the pulmonary cells were becoming dilated with an elastic spirit, while the whole frame receives at each inspiration fresh vital impulsion. The faculties of the brain get excited; the imagination becomes vivid; and the ideas flow with delightful facility. Digestion is made more active, as after gentle exercise in the open air, because the secretory organs participate immediately in the increased energies of the arterial system, and therefore there is no thirst."

It is not designed, however, to press this condensation to the extent of these experiments of Mr. James: hence I have used the expression that condensation will have "a tendency to brace the nerves and energize the system." The device that bestows upon the science of ventilation this new and valuable faculty, as has been said, will give any measure of condensation, large or small, that may be found sanatory and pleasant.

A third and an elementary change, also consequent upon this condensation, arises from the manner of its action on the mass of resident air found in the halls when ventilation commences. Under all existing systems of ventilation, this resident air is found to be an obstruction to an equable temperature and hydration throughout the halls. The new air, attempered and moistened, is at present forced in upon this great body of resident air in the halls, and although of a different temperature, the two are expected to commingle in one homogeneous mass of a uniform temperature and moisture. Thus, under present systems, the halls are made to serve as grand laboratories or mixing rooms for unequal temperatures. We find, as resulting from these unreasonable violations of atmospheric laws, that unequal temperatures and currents will prevail all over the halls.

The effect of the proposed condensation will be to remedy these objectionable results of existing systems of ventilation. Under the new method of ventilation, in cold weather, when the new air enters the hall or room, being lighter than the cool resident air, it floats near the ceiling and forms in horizontal strata, which, by constant accretions from the fan, accumulate and wedge downward upon the resident air of the hall, until the pressure has so multiplied as to force open the obstructing device and give free exit to the foul air. Then, (when the obstructing device has yielded,) as strata of new air are driven in at top of the hall, equal strata of old resident air escapes at the floor, until all the resident air has been expelled, leaving the entire air of the halls one homogeneous mass.

A fourth result to spring from condensation is to be found in its uniform and assured expulsion of all offensive air and gases that always will attend a crowded house and galleries. The movement of the air will be from the ceiling to the floor, not in streams or currents, but in a steady downward progress, of such force, however, as to deflect the breath and warm emanations from the persons of the crowd down toward the floor, thereby always presenting an untainted air for respiration.

A fifth resultant of the "new method" will be found in its large economy, it ventilating the halls with one-fourth of the volume of air now required. At present 50,000 cubic feet of air is forced into the hall of Representatives alone. All control and direction of this air is abandoned as soon as it enters the hall. It is then left to its own vagaries to get out as best it may, through chimneys, doors, or the registers on the floors. Experience has shown that very little escapes at the floor, and that foul air will accumulate on the floors and in the galleries.

On the other hand, under the "new method," a perfect command and direction of the air within the hall is maintained all the time, down to its final expulsion. The enormous waste of the present system is saved in the well-ordered appointments of the "new method." One-fifth of the air now required will give a better ventilation to the halls, and consequently four-fifths of the cost of warming and moistening the air for ventilation will be saved.

A sixth result to flow from this novel device for condensing the air in the uses of ventilation is that it will render the ventilation of the entire Capitol and of every room and space within its walls matter of easy and convenient accomplishment. Not only can the halls, the court-rooms, library and committee rooms be pleasantly warmed and ventilated, but the damp and dark vaults in the basement, now useless and mere generators of unwholesome vapors, may be made dry, and being thoroughly ventilated will become safe and valued depositories of the public archives. These benefits may also be extended to all the departmental buildings, and to the presidential mansion, if its adoption in the Capitol is successful. Already have the accumulations of Government documents overcrowded the rooms of these buildings. The demand for increased accommodations will compel the expenditure of millions for new structures; but the spaces in these buildings acquired and utilized by introduction of this improved ventilation will postpone to a distant day the necessity of such expenditure.

One other sequence of this improved ventilation and I have done. It will be found that the condensation of air within the rooms of a building will effectually protect the records and folded papers from the intrusion of the gritty dust which now eddies in upon them from the street. The compression of air within the rooms will cause an outflow through every crack and crevice and opening that will resist and repel the entrance of outside winds.

I have given these general effects or results of the "new method" without explanation of details. I will only add that "the new method" has been submitted to the criticism of the first and most eminent science of the country, (members of the Coast Survey and others,) and it has been approved by their judgments. I must now conclude by a brief reference to some alterations in the structure of the two halls of Congress, which the blundering errors of those who superintended the building of the Capitol extensions have made necessary. The wretched ventilation now inflicted on the two houses of Congress is traceable to these errors, which are the more intolerable because they were imposed on the public in violation of the elaborate and enlightened plans furnished for their guidance by that eminent engineer and architect, Charles F. Anderson.

The designs for the two halls as originally devised by Mr. Anderson would have given to the nation halls of the most perfect architectural model in the world. Anderson, who was a thorough architect, and had matured his professional taste and skill by extensive observation and study of the best models in Europe, furnished the plans and drawings for the Capitol extension. Before his plans were adopted, they had been submitted to the scrutiny of the President of the United States, to the heads of departments, committees of Congress, and to boards of learned men, such as Professors Bache, Henry, and others, for their well-considered opinions. After long and anxious examination, these eminent officials and learned savans approved the designs and authorized the work to be executed in accordance.

By what authority the superintendent of the Capitol extension departed from these designs of Mr. Anderson I have not seen: but it is certain that in execution of the work the architectural symmetry of the halls, as Anderson had planned them, was ruthlessly violated, and that all his well-studied principles of acoustics and of wholesome ventilation were subverted and reversed.

By Anderson's plan, the larger hall was to have been of about 52 feet in height; the superintendent gave it about 36 feet. Anderson designed to admit the light into the hall through side windows placed overhead, as are the windows of the rotunda, and to place the present glass ceiling above these side windows, thereby giving to the hall a lofty and magnificent appearance, and affording a light that could always be regulated by blinds and shades. The superintendent has dwarfed these lofty and beautiful proportions, and has given to the hall a flat and squat appearance, repulsive alike to good looks and a chaste architecture.

These outrages upon the admirable designs of Mr. Anderson were not, however, confined to violations of good taste and architectural appearance; with a ruthless hand the superintendent disregarded and reversed the well-studied plans of Mr. Anderson for the admission both of light and air into the halls. As just said, he dwarfed their height by 16 or 17 feet, thereby dispensing with side windows, in lieu of which he admitted light into the halls through spacious glass domes with skylights in the roof.

The glass skylights over the Senate chamber have an area of more than 3,400 square feet, and those over Congress hall present a surface measure of about 5,000 square feet. Thus, in reckless subversion of Anderson's elaborated plans, the Representatives of the people are now exposed uncovered to the terrible gaze of our summer's sun.

A second and a radical departure from the well-considered plans of Mr. Anderson, and not less deleterious in its effects, was in the reversal of his mode of admitting the ventilating air into the two halls of Congress. Anderson directed the air to be driven in at the ceiling, and to be forced downwards through the halls, and expelled through the floors. This was in accordance with the systems now in use in England and other European governments. The superintendent, however, in reversal of this system, and in face of the present approved practice, went back to the old discarded system, and

forces the air in at the floors, to be driven out at the ceilings. It is deemed to be of absolute necessity to any wholesome plan of ventilation that these elementary defects of structure shall be amended. If the halls be not protected from the solar influences of those spacious skylights, there can be no system of ventilation that will render the halls endurable in summer's heat; and the effects of this vast glass surface in the winter are also injurious to good ventilation and equable temperatures. I content myself, however, by a simple reference to the lucid and concise report of Senator Buckalew, as chairman of a joint committee on ventilation, ordered to be printed July 18, 1866.

I will suggest that the old hall of Representatives be fitted up for occupation of the Senate until the necessary alterations of the Senate chamber can be made. The lower House can then in like manner vacate their hall for the same purpose.

APPENDIX B.

To the honorable chairman, &c.:

GENTLEMEN: There are points and features of the new method of ventilation I advocate for your adoption in the two halls of Congress that require to be examined and discussed before it can be expected you will give the plan a thorough approval. There always will be doubts and misgivings as to new and untried theories in their first practical operations, and hence I desire to meet and answer before you certain difficulties of the plan which have embarrassed my own mind in reasoning to my present judgment.

The first point of solicitude in all plans of ventilation is to secure an abounding volume of pure, untainted air for breathing purposes. The new method, however, presents conditions and movements of the ventilating air unknown to all existing systems, and therefore former methods will furnish us no means of judging what volume or velocity of air is best in establishing good ventilation under the new plan.

Under the devices of the new system an absolute empire over the ventilating air is claimed and acquired. Its volume or quantity, its velocity of movement, its course or direction, may all be appointed and accurately defined. In a word, we must learn to know that the air can be made to yield to the coercion of the fan the same implicit obedience and ductility that gas does to its gasometer.

As a consequence of this high command and implicit obedience of the ventilating air, any measure or volume that is needed may be driven in at the ceiling of the hall, and, being denied all egress except at the floor, its course or direction is necessarily downward. Being in cold weather of a warmer temperature than the resident air, it will spread in the top of the hall in layers or strata, and from the continuous accretions at the ceiling these strata of new air, in swollen force, will continue to wedge downward in the hall, and impacting the lower air upon the floor, will reach a condensation in the hall that will force open the obstructing device placed in the main foul-air tube, and thus open for the air a free passage "out of doors."

Such is the mode of action under the new method, from which it is evident, as just said, that complete command of the ventilating air, in its volume or quantity, its speed or velocity, and in its course or direction, can be achieved.

With such supreme power in our hands we have to consider how it shall be used so as to effect the best ventilation in the halls of Congress. I intend, by best, that ventilation most wholesome and pleasant, and which, at the same time, will most improve the acoustics.

It is in this novelty of the proposed condensation or compression of the air in the hall that the most beneficial results of the new method of ventilation are to be found. The improvement of acoustics, the evenness of temperature, and of hydration over all parts of the hall, and the great economy in the volume of the air needed for ventilation, are resultants of this compression, which innovates on all existing systems. It is all-important, therefore, that all doubts shall be removed as to the ready practicability of achieving a compression of air within the halls to any exact pressure that experiment may show to be proper. I will now, therefore, address my explanations to this point.

First, then, what is the volume or quantity of new air to be forced into the hall that will suffice to produce a pressure of eight pounds to the square foot?—that being the pressure supposed to be proper for the purposes of the best ventilation.

There is one starting point or basis-fact from which a solution of this inquiry may be reached. The weight of the atmosphere we know to be fifteen pounds on every square inch, or 2,160 pounds to the square foot. Thence we derive the fact that two atmospheres forced into one and the same space will cause a pressure of 2,160 pounds to the square foot within such space.

From this fact, as a starting point, the measure of air required to cause a condensation of eight pounds to the square foot, within the House or Senate chamber, may be accurately computed.

The dimensions of the Representatives hall are 139 feet by 93 in width, and 36 in height; those of the Senate chamber are 113 in length and 80 in width, by 36 depth. This gives 475,372 cubic feet as the solid measure of one hall, and 325,440 as the solid measure of the other hall. We will say, in round numbers, that there are 500,000 cubic feet of air in the House, and 350,000 in the Senate chamber. The inquiry then will be to know how many cubic feet of new air, forced in upon these halls, (supposing them both to be air-tight,) will cause their condensation to eight pounds the square foot.

Now, it is very clear that 500,000 cubic feet of air forced into the hall of Representatives, in addition to the 500,000 already there, would bring two atmospheres within one and the same space, and would cause the pressure of 2,160 pounds to the foot within the hall. Then, by the rules of proportion, 500 cubic feet thrown into the larger hall would produce two pounds to the foot, (discarding fractions,) and eight pounds would require four times as much, or 2,000 cubic feet for the larger hall. A similar calculation will show that 1,400 cubic feet of air forced into the Senate chamber will give the desired pressure of eight pounds *there*.

These low figures, however, it must be observed, are not practically true, because it is not true that the halls are air-tight. Many doors leading to the halls will invite the escape of the condensation, besides other casual openings that will disturb the appointed downflow of the air. These are the practical troubles in the way of condensation, which I desire to examine closely with a view to measure their exact weight, and to show that they oppose *apparent* and *specious* difficulty rather than *real* obstruction to the practical accomplishment of this condensation, which I consider is the most essential feature of the "*new method*."

Every precaution will, of course, be adopted to forbid the escape of the air from the halls, except through the exits provided on the floors. The chimneys will be sealed up, the windows will be weather-stripped, and the doors of the hall will be doubled as in winter—so that, when opened for the entrance or departure of persons, only as much air will escape from the halls as will cause an equilibrium of pressure in the space between the doors and the air of the halls. Suppose this space between the doors to be a room measuring 1,000 cubic feet. Calculation will show that four cubic feet of air escaping into it from the hall will condense this space equally with the air of the hall! Thus we see the precise measure of the wastage from the opening of a door. Suppose there are 50 doors entering the hall of Congress and its gallery, and that each door is opened once a minute, the wastage from doors would only be 200 cubic feet per minute even then. [I have since ascertained that there are only 40 doors.]

If we suppose that the wastage from the hall from all other sources combined is equal to this wastage from the doors, the sum total of the wastage will only be 400 cubic feet of air per minute. This surely does not form an insurmountable difficulty. An additional 400 cubic feet, thrown in by the fan, gives the full compensation for this wastage. If, therefore, the fan be worked up to 2,400 cubic feet the minute, instead of 2,000, the trouble is done with. But we shall see that I contemplate furnishing 8,000 cubic feet of air per minute to meet other purposes of the plan: so that all doubts must yield on the practicability of keeping up the condensation.

The next point of difficulty to which I invite discussion is to the quantity or measure of the air per minute needed in the hall, for wholesome ventilation. Will 2,400 cubic feet of fresh air a minute suffice; and, if not, what quantity or volume per minute will be ample supply? By the present plan it will be remembered that 50,000 cubic feet of air per minute are thrown into the House to ventilate it. The idea of reducing this vast supply to 2,400 feet a minute is, I must admit, suggestive somewhat of a smothering sensation. Let us, however, examine this branch of the subject in a spirit of calm reason and judgment.

As remarked in the beginning of this paper, this new method of ventilation presents conditions and movements of the ventilating air unknown to all existing systems. These movements are novel, anomalous, *sui generis*. By all existing plans the ventilating air is abandoned to its own course from the moment it reaches the hall. All control and direction of it is *then* lost. It is *there* left to relieve its own accumulations, through doors or windows or chimney, and, if it will vouchsafe so to do, it *can* pass out at the exits on the floors, and carry with it the foul air collected *there*.

But experience has taught that this air has a nature of its own to consult; and, unless it be coerced in some way, it will not voluntarily seek these small and remote foul-air holes for escape when larger and nearer openings offer it free passage. Consequently very little air now passes from the hall through the apertures on the floors.

The theory of the new method is in strong contrast. It asserts and maintains an empire over its ventilating air *all the time*, from the blade of the fan down to its final expulsion through the foul-air conduit into open space. From the forced entrance of this air into the hall, its every movement, its velocity, and its downward course in measured strata, are all prescribed, and by intelligent appointment. In cold weather, being of warmer temperature, and consequently lighter than the air it finds in the hall, it will float at the top and spread in horizontal strata, which by constant accretion from the ceiling will wedge downward, and will impact and drive the resident

air before it; having no outlets, save those on the floor, the whole body of the air will settle down in a measured and regulated order.

The theory of the new method, moreover, requires that the air in this downward movement shall have speed and force enough to carry with it to the floor the warm breath and the offensive emanations of the human bodies, and thus preserve untainted for inhalation the higher air. This is an eminently distinctive feature of the new method. The warm and foul emanations of the crowd cannot rise to corrupt and taint the respiratory air. Once exhaled, the same air is never again presented to be taken into the lungs.

From these causes, as has been said before, lights drawn from former systems of ventilation give no data for estimating the quantity or volume of air required under the new method. It must not be overlooked, however, that the new method possesses all the power to command the air in quantities that existing methods possess. The only question, then, I wish to discuss is, what is the least quantity of air that will give full and ample ventilation? If it requires 50,000 a minute, we have it at command; if 5,000 a minute be enough, there will be great convenience and economy in the discovery.

This brings up for consideration the subject of acoustics, which should ever be connected with ventilation; and as sound is known to be more perfectly transmitted the more dense the medium, the condensation proposed for the two halls must give the new method an eminent preference. But freedom from currents and all practicable stillness is also conducive to good hearing, and must be carefully cherished in the system to be adopted. It is desirable, therefore, to give the air of the hall in its downward movement only such speed as may suffice to deflect the warm breath of the crowd and carry it down to the foul-air exits on the floor.

It will not be time wasted to pause at this point and philosophize a little on the unwonted and abnormal purposes aimed at in this new method of ventilation. To drive the warm human breath dowward, and thus to reverse the course of a warmer and lighter air, outrages all our prejudices and shocks our personal belief. It is best, therefore, to subject the proposition to the test of a strict analysis, that no grudging credence may be given to this most important feature of the new method.

The impulsion of the human breath, when it first issues from the nostrils, is almost vertical towards the ground. When it issues from the mouth, by reason of the dental and labial structure, there is given to the breath a horizontal, or perhaps a slightly downward impulsion. These are facts visible to any one in frosty weather. It is also noticeable that the breath begins to rise when the force with which it leaves the mouth has abated. This we know is due to the warmth of the breath compared with that of the air, the warmer being also the lighter. For the same reason the air in immediate contact with the human body assimilates with its temperature and rises, carrying upward the impure emanations of the skin. From these sources of taint the air in the higher parts of a crowded room becomes offensive, and if breathed over again would be unwholesome.

Now if the movement of this exhaled air be traced, (and it may readily be seen in cold weather,) it will be found to be very gentle. It rises slowly, and is deflected in any direction by the slightest currents. The smoke puffed from a pipe or cigar well illustrates the gentleness of the movement, and the ready ductility of the warm breath. It may be seen to stream downward even from the slightest current of the draught of the chimney. From these illustrations it is clear that a very slight movement of the air in the hall, in the direction of the floor, will carry with it the expired breath of the crowd, and also the offensive emanations. Whatever, therefore, be the tendency of the breath upward, if met by a downward movement of the air stronger than such tendency, the breath must deflect and be carried downward, leaving the higher air pure and untainted.

I am satisfied that a current of four inches per minute will suffice to conduct these impurities of the crowd to the floor, and it remains to show what volume of air per minute forced in at the ceiling will cause a down movement of air in the hall having a speed of four inches the minute. On this point I will submit the following estimates:

The area of the hall of Representatives at the ceiling (including the galleries) is $139 \times 93 = 12,900$ square feet. One foot in depth of this area will measure 12,900 cubic feet, and if 12,900 cubic feet of air per minute be forced in at the ceiling, it is obvious that the same measure will be wedged out at the floor, (there being no other outlet,) and that thus a downward movement of 12 inches a minute will be effected in the whole body of the air in the hall. If, therefore, the fan shall be worked to drive 12,900 feet the minute into the hall, the downward flow of the air will be at the speed of 12 inches the minute, which is three times the velocity called for. I am, therefore, warranted in the conclusion that for the purpose of carrying downward the breath and other impurities of the crowd, and of protecting the overhead air from all such offensive taint, 4,000 cubic feet of fresh air per minute will be found an ample supply.

The last point I wish to discuss in this paper is, whether the 4,000 cubic feet per min-

ute will suffice to supply the crowd on the floor and in the galleries with breathing air and an abundant ventilation. In considering this part of the subject, we must hold in view all the conditions and movements of the air induced by the action of the new method. We must remember that it is guarded against all taint or corruption of the higher air, as it will be continuously presented for inhalation; it has forced downward the breath and the warm emanations of the skin, and in fine it only leaves for calculation the quantity or bulk of air required for the actual inhalation of the crowd. On this point I present the following estimates:

The House is overcrowded when there are 1,000 persons in the galleries and 500 on the floor. The Senate never contains this number. All the books tell us that a healthy man draws into his lungs 25 cubic inches of air at a breath, and that he inhales 20 times a minute. There are 1,720 cubic inches in one cubic foot; so that the man actually only needs for inhalation one cubic foot of air every nine minutes. This shows that 500 cubic feet of air a minute will measure all the air actually taken into their lungs. This, therefore, is all that is required for breath, as it is the full capacity of their lungs. But a greater volume than this, however, will not be wasted; for being constrained downward to the exits on the floor, it will remove in its descent the air next the body, which has been warmed by that contact to the temperature of 98°, and will substitute its own temperature of 68°, thereby greatly refreshing and invigorating the whole system.

I have thus shown that 500 cubic feet of air is enough for inhalation; 2,000 cubic feet for the condensation; and 4,000 per minute will suffice to produce the down movement of the air at four inches the minute. But to insure all these objects, let us force in upon the hall 8,000 feet the minute, if it be found on trial not to injure the hearing within the hall.

I have presented these views to show how unreal are the apparent difficulties which oppose the adoption of the "new method" of ventilation. I need say nothing of its great economy in requiring the use of about 5,000 instead of the 50,000 cubic feet now demanded by the present system.

IMPROVEMENT OF THE HALLS OF CONGRESS.

February 20, 1865, Mr. Buckalew submitted the following report:

The Joint Select Committee of the two houses of Congress appointed at the last session to examine into the present condition of the Senate chamber and hall of the House of Representatives, as regards lighting, heating, and ventilation, and their acoustic properties, and the defects and disadvantages existing in the same, make the following report:

That pursuant to the resolution of appointment they have obtained from Charles F. Anderson, architect, a statement of the principles upon which he proposes the improvement of the halls of Congress, as regards the particulars above mentioned, and also estimates of the expense that will attend the proposed alterations, and they append the said statement and estimates to this report. They have also obtained plans and drawings of the proposed changes of the halls and Capitol wings, as authorized by a clause of the miscellaneous appropriation act of 2d July, 1864, which are deposited with the secretary of the Senate for examination by the members of both houses. The committee have also taken the voluntary testimony of a number of witnesses upon the several subjects covered by the present inquiry, to enable them to come to intelligent conclusions, and they now beg leave to submit that testimony in connection with this report for the information of Congress.

The committee propose, in the first place, to examine the several defects alleged to exist in the present arrangements relating to the halls of Congress, and particularly those relating to their ventilation; next to state distinctly the character of the changes proposed; and, lastly, the time, manner, and cost of their accomplishment.

First, then, as to existing defects:

PLACE OF OBTAINING AIR.

1. The air for ventilating the halls is now taken from the levels of the terraces, between the wings and the old Capitol building, on the western side. To these situations much dust and other impurities are carried by the action of winds, subjected to the influence of eddies, and taken with the air through the ventilating passages into the halls. And in warm weather the terraces and adjoining walls, becoming heated, affect very considerably the temperature of the air obtained. Reference upon this point of the inquiry is made to the testimony of Dr. Antisell, and Mr. Forney, the engineer in charge of the ventilation of the House of Representatives. It is manifest that the air

introduced into the halls should be obtained from places not subject to the accumulation of impurities, or to the undue production of heat.

OVERHEATING THE AIR.

2. By the examination of the engineer in charge of the heating and ventilating department of the Senate chamber, it appears that the air, on its passage to the chamber, is heated exclusively by steam, introduced into mazes of pipes for the purpose. Hot water is not used, and it seems certain that the air is overheated, and thereby subjected to injurious changes. Professor Wyman says:

"In all cases in which it may be necessary to warm the fresh air required to be supplied to an inhabited room or cell, it is essential to health that the increased temperature should be derived from a moderately-heated surface; hence the advantage of using water as a medium of heating. In a hot-water apparatus of ordinary construction the temperature of the surfaces, when exposed to a current of air, will never reach the boiling point, and it is obvious that they may be regulated in any lower degree that is likely to be useful."

Among the conditions prescribed for the warming apparatus of Pentonville prison—the "model prison"—was the following:

"That the entire radiating surface should derive its temperature from the circulation of hot water, and that it should be of such an area as would maintain a temperature of 60° in the cells when the external atmosphere was at 32°; further, that under ordinary circumstances the temperature of the heating surface should not range above 100° to 120° of Fahrenheit."

This point of overheating the air demands amendment, which must be secured in any new arrangement regarding ventilation.

DEFICIENT MOISTURE.

3. But one of the most manifest and material defects in the ventilation of the Capitol wings is the exceeding aridity of the air supplied. To this point the committee have given particular attention, and the information obtained upon it is most conclusive in condemnation of the existing arrangement. Both health and comfort are disregarded in forcing into the halls air containing but one-third to one-half the moisture or vapor of water required at the temperature to which it is raised. It is to be taken for granted that the natural constitution of air at any given temperature is better adapted to life and human comfort than an artificial one can be, and it is to be secured as nearly as possible in all structures designed for human occupancy. In a free atmosphere the demand for moisture caused by increased temperature is fully supplied from natural sources. But in moving air through a confined space destitute of watery vapor, and subjecting it on its passage to the action of heat, while its character must undergo a change as to temperature and density, there will be no corresponding change in the amount or proportion of moisture it contains. In other words, moisture must be imparted to it by artificial means, if its true natural constitution is to be maintained. That a principle so well known and so indisputable should have been ignored in the ventilation of the Capitol is most surprising, and indicates, if it does not prove, incompetency or indifference to duty in the superintendency of the building.

Doctor Reid observes that "the moisture in the air is not to be regarded as an adventitious ingredient, but rather as an essential component of atmospheric air. It requires in general to be added to air in cold climates in winter in proportion to the temperature communicated to it before it approaches the person. If cold air be heated in spring and summer by natural causes, it absorbs a proportional share of moisture in general from the surface of moist ground, lakes, and rivers, or from the ocean, and thus reaches the system in a congenial condition. On the other hand, if cold and dry air be heated artificially without receiving moisture its increased power of absorbing moisture renders it offensive to the system."—*Reid on Ventilation, secs.* 341–43.

"The amount of evaporation into equal spaces is dependent upon the temperature, and increases considerably on a small increase of heat." Between 32° and 100° the amount of evaporation is doubled by the addition of about 20°, or at 52° it is double that of 32°. * * * In winter the air, when extremely cold, is proportionably free from moisture. The true time, accordingly, when moisture ought to be applied to air is not when it is warm in spring and summer, but as it is warmed artificially in winter. The temperature and moisture of the air are certainly the most important circumstances that demand attention after securing air of sufficient purity." (*Ib., secs.* 350, 436, 511.)

Professor Wyman says that "air holds in solution a variable amount of aqueous vapor, limited by the temperature. The influence of this agent upon the human system is exceedingly important. The lungs are continually exhaling moisture, its quantity depending upon the hygrometric state of the atmosphere. If the air be too dry, the lining membrane of the lungs, throat, and mouth may be deprived of necessary moisture so rapidly that an uncomfortable degree of dryness, or even inflammation

may be induced. Undoubtedly the best constitution of the air is that which nature affords. During the summer months the air has gradually increased in temperature, and appropriated from rivers and other sources that amount of vapor which is required. In our houses we should imitate the same course, and, heating air from below 32° to 70°, provide a sufficient supply of water." (*Wyman on Ventilation*, pp. 190, 191, 196.)

"Air changed in temperature by warming without increased moisture is apt to produce unpleasant feelings and painful sensations in the chest, which are often attributed to too great heat. In very dry air the insensible perspiration will be increased, &c. The objection lies against *heated* air, no matter how heated. Stoves and air furnaces with their red-hot surfaces are undoubtedly worse for the air than hot water apparatus, which never scorch it, yet the latter may pour into our apartments a withering blast of air at 150°, which may be potent for mischief. The only way that hot air can be made healthful and desirable is by an effectual plan of artificial evaporation." (*Dr. Youmans's Handbook of Social Science*, 308.)

Appended to this report is a paper furnished the committee by Dr. John A. Rowland, showing the capacity of air for moisture at different temperatures, both as to volume and weight, to which reference is made for further information upon the present point. The figures are obtained from works of reputation, and they show that the air of the halls during the winter and spring requires two or three times the amount of moisture actually contained in it; for its aridity, caused by heating it, is modified in no way whatever, not even by leakage of doors and windows, as in the case of an ordinary apartment.

But what determines the condition of the air in this respect with perfect certainty is the examination given it by Dr. Wetherill, of the Smithsonian Institution. He examined the air of the Senate chamber on the 24th of January, and on February 9th, and states the results in his testimony. Indicating the saturation point of air at any given temperature by the number 100, we have a standard established for comparison, when ascertaining the quantity of moisture actually present in any specimen of air. Upon ascertaining the amount so present, it may be indicated by a number which will bear the same relation to 100 that the amount found present bears to the amount which would be present if the air were completely saturated or contained moisture to the full extent of its capacity. And in such case, the number indicating the quantity present is called the "relative humidity" of the air examined.

Now the mean annual relative humidity of atmospheric air in England has been ascertained to be about 75°, saturation being, as before stated, 100°. Mr. Roscoe states that in the House of Lords the air is pleasant to breathe when its relative humidity ranges between 55° and 82°. But Dr. Wetherill found the relative humidity of the air in our Senate chamber on January 24th to be as follows: In ladies' gallery, near reporters' gallery, at 2¼ p. m., 27. In same, near diplomatic gallery, 27. On same day, at 3 p. m., the relative humidity of the external air entering the ventilating fan, was 56.

On February 9th, with a relative humidity of external air at 55 at 2½ p. m., he obtained the following results in the Senate chamber: In southeast corner of chamber, on a level with desks, at 3½ p. m., relative humidity, 20; in diplomatic gallery, at 4 o'clock, 21.

These astonishing but indisputable results prove that upon that occasion less than one-third the proper amount of moisture was present in the air of the chamber.

An observation taken by him at 4.30 p. m. of the same day in the air-space above the ceiling is also instructive. He found the temperature to be 64°, while the temperature in the hall below at the previous observation had been 70.9° upon the floor, and 68° in the diplomatic gallery. An enormous influence of the roof in producing cold, and affecting the air of the halls, is shown by these figures. It was a cold day, with an external temperature of 30.6°.

It may be added that by observations taken at the Smithsonian Institution for the months of February and June, 1859, there being three observations daily, the mean relative humidity of the atmosphere for the former month was 71, and for the latter month, 69. Therefore, on the 9th of February, 1865, the air used in ventilating the Senate chamber, with an external February temperature, and an inside temperature of June, had a point of relative humidity in the chamber that required to be multiplied by 3½ to raise it to the proper Washington average.

With good reason, therefore, does Dr. Antisell declare in his testimony that one of the capital defects of our ventilation is the want of hydration of the air of the halls.

Some attempt has been made to hydrate the air recently, but in a very insufficient manner, and without material effect. The laudable effort of the present Sergeant-at-Arms of the Senate, with insufficient space and facilities at command, to hydrate the air of the Senate chamber, deserves commendation.

But to accomplish the object in view a radical change in existing general arrangements is required. Dr. Reid states that, in ventilating the English House of Commons, when it was crowded, he often exposed the air furnished to 5,000 feet of evaporating surface, to impart the necessary moisture, *and subsequently made the air flow through jets of water.* (*Youmans, sec.* ..4..)

The ideas that have obtained in the ventilation of the Capitol may be estimated by the statement made to the committee by the present architect, that he proposed to hydrate the air of each hall by passing it over an evaporating surface of 40 square feet. The committee are not prepared to recommend this particular experiment. (A subsequent statement was, 30 feet of heated water, or a surface a little exceeding 4 feet by 7.)

"When dry air is exposed to a source of moisture, a considerable *time* must elapse before it will become saturated. The diffusion of vapor into hot air is much more rapid than into that which is colder, but it is not at all instantaneous. Mr. Daniell observed that a few cubic inches of dry air continued to expand by the absorption of humidity for an hour or two, when exposed to water of the temperature of the surrounding air."

It follows that the dry and warmed air for supplying rooms of great magnitude must be passed over an evaporating surface of great extent, in case that mode of hydrating it be adopted. Doubtless, warming the water would increase the efficiency of the plan. Dr. Antisell recommends spray or jets of water thrown into the air at a right angle to its current, which would no doubt be an effective and satisfactory mode of accomplishing the object where the necessary facilities can be established, among which space is indispensable. The objections to the use of steam, on an extensive scale, for hydration, are, the production of noise, and, as alleged, of odor, and its imperfect dissolution in the air before entering the chamber. It passes on with the current of air for some time before it becomes dissolved and incorporated with it, and moisture is deposited upon all surfaces with which the volume of air comes in contact. There is no arrangement for introducing steam into the air passing to the halls, but it was provided for the air directed to the committee rooms and passages. The plan was not found to work well, and has not been in practice.

DUST RISING IN THE HALLS.

4. Dust rising in the halls from the floors. This defect arises from the introduction of air through horizontal openings in the floors, and is an inconvenience which should be abated, if possible.

In Dr. Reid's arrangements for ventilating the former House of Commons, mats and Russian scrapers were provided in the lobbies to secure the greatest possible exclusion of every source of impurity from the floor: the air being admitted through the floor by numerous apertures.

This difficulty of dust rising in the room, as well as the introduction of refuse substances into the horizontal openings in the floor, would be mitigated, though not entirely removed, by the introduction of the air through the risers of the steps behind the seats of members. That was the original plan, but it was abandoned, as was also the free introduction of air into the sides of the room, because of the unpleasant currents produced. No doubt the latter effect would be decreased, if not removed, by proper hydration of the air; for it is quite certain that a current of dry air, although at a high temperature, will produce chilliness, on account of the rapid evaporation caused by it.

INEQUALITY OF TEMPERATURE.

5. Unequal temperature in the halls at the same level. The statements of temperature which appear in the evidence establish and illustrate this point; the temperatures given of the hall of the House are average ones; observations of a number of thermometers, at the same level in various parts of the hall, differing several degrees from each other, being taken. The Senate chamber temperatures are those of single instruments with their particular locations noted, differing, in some cases, five degrees or more from each other at the same level, but on opposite sides of the chamber. The certain result of these differences of temperature is to cause unequal movement of the air and to disturb the regularity of the ventilation. The air will ascend unequally in different parts of the halls, and perhaps, also, some disturbance of sound will be thereby produced.

EXTREME HEAT.

6. Extreme degree of heat in the halls. The thermometrical observations, besides showing differences of temperature, show also an excessive degree of heat. The average exceeds 70°, whereas it should not exceed 65° to 68°.

"In private houses the air should never be allowed to remain above 70° when warmed by heated air; when heated air is used in connection with open fires, or other radiating bodies, the temperature will not often require to be above 65°." (*Wyman*, p. 188.)

"The best temperature for a room is 65° to 68°." (*Youmans, sec.* 21.)

Temperature in former House of Commons.—"The house is heated to 62° before it is opened, and maintained generally at a temperature varying between 63° and 70°, according to the velocity of the air passing through the house." (*Reid, sec.* 659.)

A proper temperature is fixed by Dr. Antisell, in his testimony, at 66°. In fact, a

temperature exceeding 70° in the halls would be intolerable were it not for the aridity of the air; because of *that*, rapid evaporation takes place, rendering individuals less sensitive to the presence of heat. But the degree of heat to which individuals are subjected in the halls is probably injurious, and is in more marked contrast to the external temperature than is desirable. These observations relate to the winter and spring months, but the temperature of the halls in summer is often offensively high during both day and night sessions; for the heat passing through the roof into the halls by day, and the heat thrown down by the lights at night, are equally intrusive and objectionable. There was no necessity for establishing the conditions from which these effects follow; and the heat, which sometimes reaches nearly 90° in the halls, is productive of much discomfort, is injurious to health, and obstructive of legislation. In summer the air is sufficiently moist, but temperature is less subject to regulation than in winter.

COMMUNICATION WITH AIR SPACE ABOVE THE CEILING.

7. The air of the halls is not kept distinct and apart from the air of the spaces above the ceilings. It is, therefore, subject to the influence of the roofs and of the lights. From this cause the ventilation of the halls is disturbed, and rendered imperfect, as will be shown under subsequent heads.

THE ROOFS.

8. The roofs are exceedingly objectionable as they exist at present, composed in part of metal and in part of glass, generating cold or admitting heat according to season, and conducting the noise of storms enormously and offensively to the halls. In erecting them, it seems to have been forgotten that this Capitol was not to be an Egyptian or Grecian temple, under a genial sky, nor even a Roman church, in the mild climate of Italy, but a great structure for the use of legislative bodies, in a comparatively inclement location upon the banks of the Potomac. Windows upon the sides, for lighting the halls, if made double, would not only have accomplished their office more perfectly than a glass roof, but would have protected the air of the chamber from all injurious influence of the external atmosphere, and from the intrusion of all external sound; and even the entrance of solar heat, now enormous, and incapable of regulation by the roof, might have been excluded, by shading, when necessary, the windows exposed to it. Light from side windows would be soft, natural, cheerful, and diffused, producing perfect illumination of the whole interior space, including the galleries, now so unequally and imperfectly lighted. And, finally, windows, unlike the roof, might be thrown open at pleasure, and thus, at proper seasons and upon fit occasions, rapid and thorough ventilation of the halls secured.

THE LIGHTS.

9. The particular arrangement for lighting the halls by gas jets above the ceiling is another defect requiring attention. The jets are very numerous—those used for lighting the hall of the House exceeding twelve hundred in number. The amount of heat created by them is very great, and the quantity thrown down into one of the halls at a night session increases the temperature of the hall from three to five degrees. This is peculiarly disadvantageous in summer, and renders night sessions uncomfortable, there being no effective arrangement for cooling the hall. There is an unnecessary consumption of gas, and the products of combustion are not effectually removed.

Dr. Reid says: "When any vitiated air is produced by a gas lamp or other artificial light, or by any manufacturing operation, too much importance cannot be attached to the desirableness of involving it directly in a stream or current of air by which it is conveyed to a channel where it cannot possibly contaminate the air of respiration." (S. 458.)

It is to be remembered that there is extensive communication between the hall and the air space above the ceiling, where the lights are placed, through numerous apertures along the ceiling, allowing impurities of combustion to pass into the halls with any downward current. And Dr. Antisell explains, that the accumulation of hot air under the roof without sufficient means of exit is to back up against the outgoing currents from the hall and prevent their escape.

There can be no doubt that comparatively few lights arranged with reflectors and ventilating chimneys would light the halls perfectly, would throw down but little heat into them, and would thoroughly ventilate the air spaces above the ceiling, assuming that they were cut off (as they should be) from any communication with the halls.

IMPERFECT REMOVAL OF AIR.

10. One principal defect of ventilation is, the imperfect removal above of the vitiated air of the halls. Under this head two points are to be considered: 1st. That the

avenues of escape for the air are inadequate; and, 2d, that no exhausting power is applied. Whatever of escape takes place is simply from the natural ascent of heated air, and this action is insufficient and irregular from defective arrangements. In the case of the Senate hall the apertures for the escape of the air have a deficient capacity of one-sixth as compared with the entrance shaft, or passage below. The velocity of escape is deficient also to the extent of one-third as compared with the entrance movement produced by the fan. Great irregularity and imperfect ventilation are the necessary results.

As to the application of artificial power for the removal of the air, Dr. Antisell says: "The chief power should be placed at the point where the air is thrown out or removed from the building. I look upon a fan for the introduction of air as of secondary importance compared with a fan placed at a point where the air is removed. The object is to remove the air that has become impure, and it may be done much easier and with more certainty if the power is applied at the removing point."

Question. "Do you consider the application of power for the removal of air from a chamber more important than for its introduction?"

Answer. "Certainly; that is the main point. The main power should be applied where the air is to be removed, and for this reason: You are never sure, in driving air in, that it arrives at the point desired: but if you take it out of the room the thing is palpable."

Now, at present, the air is forced by fans into the halls and then allowed to take its own course, subject, however, to all the disturbing causes which exist in the halls or above them. No power is applied to produce certainty and regularity in its removal.

CARBONIC ACID GAS.

The presence of carbonic acid gas in the halls is, no doubt, in excess of the quantity contained in the external atmosphere, but the committee have not been able to obtain any exact determination regarding the quantity present, either at ordinary sessions or upon extraordinary occasions. The detection of this gas, and an exact determination of the amount of it contained in air, require skill, careful attention, and instruments and materials of analysis of much perfection. Of atmospheric air in a state of ordinary purity, carbonic acid gas constitutes but about four parts in ten thousand; and even in air overcharged and rendered unhealthy by its presence, the quantity contained is exceedingly small. But the examination upon this point now being prosecuted by Dr. Charles M. Wetherill, of the Smithsonian Institution, will furnish information approaching exactness, as his capacity and fidelity are both unquestionable. In the absence of reliable information, no clear opinion can be formed upon this subject, but the committee are induced to think that the contamination of the air of the hall from this cause is not very excessive or injurious. The reasons for this opinion are, the great size of the halls, the fact that notwithstanding defective movement of the air in ventilation, the quantity of air removed within a given time must be very considerable, and that the halls are usually occupied but a few hours at one time. Upon extraordinary occasions, when the galleries are well filled, it is probable that defective ventilation permits an unhealthy accumulation of this pernicious gas, and its enormous production by the lights, without perfect exclusion from the halls, may produce contamination of the air, even below the ceiling.

Such, then, are the existing defects to which the attention of the committee has been directed, and they may be briefly summed up as follows:

That the air is taken from an improper place, where it contains dust and is overheated in summer. That it is over-heated by steam-pipes. That the air as introduced into the halls during the winter and spring months of the year does not contain more than one-third to one-half the moisture or vapor of water required at the temperature to which it is raised. That its aridity is a capital defect, and demands radical change and amendment. That dust rises in the halls from the introduction of the air through the floors. That temperatures are unequal in the halls at the same level.

That the heat is extreme in the halls, at least by 5° or 6°, and most excessive in summer, both by day and night, from the influence of the roofs and lights.

That the air of the halls is not kept distinct and separated from that between the ceilings and roofs.

That the roofs are very objectionable both from their construction and the materials of which they are composed, and that for the glass roofs, side windows, made double, would be an admirable substitute.

That the present arrangement for lighting the halls is bad.

That the removal of the air from the halls is imperfectly accomplished, the outlets being inadequate, and no exhausting power provided.

THE PLAN OF IMPROVEMENT.

The changes and improvements proposed by Mr. Anderson, the architect, are stated in detail in his report to the committee, which is appended hereto, and are shown and

illustrated by his plans and drawings which accompany it. He proposes to obtain air from situations upon the bank west of the building, through vertical shafts of some elevation; to conduct it through protected passages into the sub-basement, and then conduct it upwards through appropriate passages to air-chambers outside and near the upper part of the halls. From these distributing chambers it is to pass through ducts over the ceilings, and obtain admission to the chambers through the present apertures in the ceilings. The entire movement of air so far is to be produced and regulated by a powerful fan placed near the bottom of the ascending passage, and provision is made for warming the air upon its way by hot-water pipes, and for cooling it in summer by the use of ice. He proposes also to place jets of water in the outer entrance shafts, and to provide most ample and effectual arrangements for hydrating the air before it reaches the ceiling. The space at command will enable this to be done perfectly, thus removing wholly one of the main defects in the existing arrangement. The removal or exhaustion of the air from the halls will be through the floors and through the present passages used for the introduction of air, powerful fans being again used for accomplishing this purpose.

THE PLAN CAN BE REVERSED.

Now, whatever opinion may be formed of the merits of the plan thus far, as to the movement of air in the process of ventilation, it is manifest that it possesses the merit of being capable of exact reversal. At any time, if desired, the air may be introduced from below, conveyed upward through the halls, and exhausted through the proposed entrance-passages of the place: in which case it would become, as to its general features, almost the identical plan successfully adopted by Dr. Reid for the ventilation of the former House of Commons. In fact, such reversed plan would have a material advantage over the Reid arrangement in the use of an effective exhausting-fan instead of a fire and chimney. Dr. Antisell and Mr. Cluskey correctly state that such reversal of the plan, as to direction of the movement of the air, could be made with little expense and alteration if desired hereafter. This consideration meets any possible objection to the downward movement of air through the halls, by those who may not be convinced of its utility, efficiency, and success.

ELEVATION OF CEILINGS AND ROOFS.

But a most material part of the proposed plan—that which involves most of expenditure and requires most of careful investigation—is the elevation of the ceilings and roofs, with the accompanying and consequent changes.

It is proposed to elevate the ceiling and roof, in each wing, about fifteen feet: to make the roof double, the inner one counter-ceiled with non-conducting material; to substitute a limited number of lights, with reflectors and ventilating chimneys, for the present numerous gas jets, and to insert windows around the whole upper part of the hall in the space gained by the elevation of the ceiling and roof. Thus, the air-space above the ceiling, separated entirely from the ducts through which the air for the hall is introduced or exhausted, will be ventilated by the chimneys of the lights: all the products of combustion will be at once removed; abundant light, with little heat, will be produced; all influence of external heat or cold and all noise from storms will be prevented by the double roof and the insulated air space above the ceiling, and perfect illumination of the hall and galleries, with other advantages, secured by the side-windows introduced. There can be no doubt that these would be most valuable improvements upon the points involved in this inquiry, to wit, the heating, ventilation, and acoustics of the halls of Congress.

The laws of architectural proportion require the elevation of the ceilings, and the appearance of the halls (and particularly the hall of the House of Representatives) would be greatly improved thereby.

The original plan of Mr. Anderson, which was mainly followed in the construction of the halls, and in their location in the center of the wings, contemplated windows above, as now proposed, and it is not likely that any competent architect would ever propose such rooms, so located, without any possible access to solar light except through the roofs.

Besides, it is insisted upon by professional gentlemen, and appears to be true, that the architectural effect of the Capitol, viewed externally, would be improved by the moderate elevations proposed to be added upon the wings. The sky line of the structure would be somewhat broken, which would comport with the style of Roman art upon which the Capitol was originally designed—the Roman-Corinthian order—and the attention now fixed, concentrated, and absorbed by the great central dome, would take in the whole structure and recognize the wings in which the great legislative houses, composing the Congress of the United States, are assembled.

The elevations would recede inward some distance from the outer vertical line of the wings, and none of the present or proposed exterior work upon the wings would be disturbed.

OBSERVATIONS UPON THE PLAN.

Recurring to the details of the plan of changes already stated, the committee have some additional observations to submit upon particular points.

It is questioned by a most competent witness examined by the committee, whether entrance shafts for the external air so high as 25 or 30 feet are necessary or expedient, and also whether jets of water in those shafts would be an advantage. The committee conclude that neither point is very important, and, however determined, will not materially affect the general plan: a proper place for obtaining the air being the main object to be secured in the first instance. As to passing the air over ice in the summer for the purpose of cooling it, the committee think that the use of cold water in the pipes used in winter for warming the air would usually be sufficient for a proper reduction of temperature. In hydrating the air the use of an extensive system of jets or spray of water, reasonably warmed, in the ample space at command by the plan, would be the most efficient and satisfactory. Any use of steam must be in moderate quantity, and at some considerable distance from the point of entrance into the chamber, to permit its perfect absorption and dissolution in the air. Level evaporating surfaces would require to be of great extent; their arrangement might impede the movement of the air in ascending, and might cause accumulation of dirt or impurity. The plan of hydration here suggested is contained in the testimony of the intelligent and able witness already mentioned, and is concurred in by the architect. Another suggestion from the same source, as to an easy improvement of the openings of the ceilings for the passage of air, is believed to be judicious. The windows to be introduced into the upper part of the halls should unquestionably be double, and, in the opinion of the committee, no stained glass should be used in their construction.

THE DOWNWARD MOVEMENT OF AIR.

But one additional feature of the plan remains to be considered—the proposed downward movement of the air through the halls. In his "Notes upon Acoustics and Ventilation," submitted by Captain M. C. Meigs to Jefferson Davis, Secretary of War, May 19, 1853, the advantages of the descending movements are stated to be, the avoidance of all eddies, a nearly homogeneous and tranquil atmosphere, and the immediate removal downward of any dust from the carpet, which would thus be prevented from rising to be inhaled into the lungs; and it is insisted upon that good acoustic results would be secured. The plan of Captain Meigs for the ventilation of the halls of Congress was undoubtedly derived from Mr. Anderson, whose plans, with printed explanations, were in his possession for some time, and obviously adopted and followed to a great extent in the construction of the wings. The "Notes on Acoustics and Ventilation," elaborating the advantages of the descending movement, are therefore appended to this report, and in connection therewith the emphatic indorsement of them as correct and judicious by Professors A. D. Bache, of the Coast Survey, and Joseph Henry, of the Smithsonian Institution. The views thus presented and indorsed were the views of Mr. Anderson, and are exactly applicable to the plan now proposed by him, and they retain whatever of soundness and force they possessed in 1853, notwithstanding they were subsequently departed from in the construction and arrangements of the halls.

But there are two material advantages of the descending movement of air which were not stated in the "Notes" referred to, to wit: the equalization of temperature in the halls, and particularly near the floors, and the economy or saving of heat; both of which are important and evident. They are stated by Dr. Antisell, and to be taken into consideration in determining the plan now under consideration. For the difference of temperature upon opposite sides of the hall, constituting one of the existing defects, would be wholly avoided by the downward movement. The tendency of the air after its admission at the ceiling, and during its progress to the floor, would be toward equalization and uniformity of temperature, and the *movement* also would be comparatively regular until acted upon very near the floor by outgoing currents. The argument, therefore, for improved acoustics by the downward movement, as given in the "Notes," is strengthened by these considerations. The facility of heating the hall, and economy in the use of heat for that purpose, would also be greatly increased; for a considerable time is now required for warming one of the halls, inasmuch as the heated air when first introduced passes rapidly to the ceiling and roof, the colder air remaining in, or falling to, the lower parts of the hall. The process must therefore be continued until the entire space is thoroughly warmed, and if the air is introduced at a proper temperature several hours will be required for this purpose. Besides, a great amount of warm air is wasted in heating the space between the ceiling and roof, and a large amount necessarily lost by the roof itself, as before mentioned. But in introducing the air above, as proposed, with an exhausting power below, the room can be warmed rapidly, the exhausting fan withdrawing the cold air with certainty and dispatch and permitting its place to be occupied by the descending

volume of warm air. No heat will be lost by the roofs, nor diverted to the air spaces between them and the ceiling.

The "Notes" correctly state that, "by a steam-driven fan, or other mechanical means, we can pump air, in any desired quantity, into any spot to which we choose to direct it."

The fan is now the accepted instrument for the movement of air by either the plenum or vacuum impulse, where great efficiency is desired, and its improvement has been carried so far as to leave little to be desired. Where the size of a building warrants its use, it gives any desired power with certainty and cheapness, and is capable of adjustment in almost any position where the limited space required by it can be obtained. And it has superiority over a chimney with fire, in its capacity to move air in *any* direction, and to move it regularly and with greater efficiency. Placed as a power to supply or exhaust a room, its force can be exactly calculated and the result intended precisely accomplished. The exhaustion of the air of a room by it in a downward direction can be made at pleasure. It is simply a question of the application of a power entirely at command, in an intelligent manner.

A few notable instances of downward movement in ventilation may be mentioned, and first that of the model Pentonville Prison, of which Professor Wyman says: "The arrangements which have been in operation ventilating and warming the cells, and maintaining an equable, general temperature within the prison, have been attended with complete success." The air is introduced through horizontal passages warmed by hot-water pipes, and, passing upward along flues, is admitted into each cell at the top immediately under the ceiling. It is withdrawn from the cell on the opposite side, at the floor, and passing upward through flues is eventually discharged by a high shaft above, into which the smoke-flues from the heating apparatus also enter. "It will thus be seen that a communication is established, first, from the outer air through the warming apparatus to the top of each cell, and thence from the floor of each cell through the extracting flues and ventilating shaft into the outer air again."

"A perfect diffusion of air takes place in the cell, the difference of temperature at the ceiling and floor can scarcely be detected, and will seldom exceed one degree, and it may be inferred that the difference of power required for extracting the air at one or the other of those levels would be inappreciable."—*Wyman.*

Of course, if the air were required to pass down from the cells to the basement, some appropriate power would be necessary to accomplish the movement.

The ventilating movement of air, as above described, is assisted in the winter by the smoke and disposable heat in the shaft above, from the heating apparatus, and in summer a small fire, maintained at the bottom of the shaft, is used. In short, the assisting power used is very slight, and yet it is said by an intelligent author that, "so admirably is the ventilation of the building contrived and kept up that there is not the least sense of closeness prevading it; for we feel, immediately we set foot in the place, how fresh and pure is the atmosphere there."—(*Mayhew's Prisons of London*, p. 120.)

A diagram of the fine Portland prison, showing the introduction of air into the compartments, both above and below, on one side, and its exhaustion on the opposite side at the floor, is to be found in the Prison Commissioner's Report, volume 29, for the year 1850.

In the case of the New York Hospital, upon Broadway, designed by Mr. Anderson, and where the plan of ventilation is successful, the air is obtained through shafts of neat appearance about twelve feet high, placed outside the building; is carried into a passage of the sub-basement, from thence admitted to the heating apparatus above, there warmed by hot-water pipes, and permitted to ascend and enter the wards upon the sides. It is removed upon the opposite side, through openings into flues above and below, either of which may be used, but those at the floor are found most efficient in practice, and remove all offensive odors of wounds and sickness from the room. The exhausting flues are connected with a small room above, in which hot-water pipes are placed to assist the movement and discharge of vitiated air. The statement of the engineer in charge is attached to this report, and confirms the opinion of a member of the committee who visited the building, that the air of the wards is good, and the whole arrangement of ventilation judicious. The use of a fan would increase efficiency of movement, if that should be desired, in this or any other building of like arrangement.

In the case of the new emigrant hospital now in course of erection on Ward's Island, New York, the air is obtained through an elevated shaft placed some distance from the building, and conducted through brick ducts, and then upward through iron shafts, through openings in which it is admitted into the different wards. It is removed through openings near the floors, behind the patients' beds, and discharged into the atmosphere in the usual manner. The letter of the architect, describing the plan, is hereto attached.

OBJECTIONS CONSIDERED.

Professor Wyman states very clearly the objections to the downward movement of air which have prevented its general adoption in buildings with much force and clear-

ness; but it will be observed that they have no application to the plan now under consideration. The first is, that this movement requires that the openings for the escape of the air should be nearly as numerous and diffused as those for its admission in the ceiling, and for most evident reasons. Ordinarily, however, such numerous apertures at the floor cannot be secured; but in our case they already exist, and the objection fails. Another objection in ordinary cases is, that in the downward movement the lights must be provided with air entirely separate from that which supplies the room, in order that the gases and other products of combustion shall not be breathed. But in the present plan the separation of the space where the lights are placed from all communication with the air of the hall is one of its main features, and easily secured. We may add, that the perforation of the ceiling for the diffused admission of the air is often inconvenient or impossible, and that facilities for operating an exhausting power below do not exist. None of the ordinary difficulties opposed to the descending movement are, therefore, to be encountered in the present case. Its practicability, however, is admitted by our author in strong language, and its desirability indicated where the conditions exist for its application. He says: "The flow of air may, when under the control of an efficient moving power, take any direction that may be desired: it may move from below upward, or the reverse, or in both directions at the same time. * * There is no impossibility of producing a constant and equable downward movement. * * * The unoccupied ceiling, in its whole extent, may be used for the admission of air, which may reach the lungs uncontaminated by dust or contact with the body. This is the movement which constantly arises in rooms heated by means of fire-places, &c."

He explains that heated air first rises to the ceiling and afterward, upon cooling, descends, and is removed by the chimney.

It is a common practice in ventilation, upon the removal of ascending air at the top of the room, to take it down a side passage and deliver it into the external atmosphere. This may be accomplished by a fire-place at the bottom of the passage, connected with an upright shaft or chimney, as in the case of the temporary House of Commons, or much better, both as to efficiency and regularity, by an exhausting fan. But manifestly this downward exhaustion of air accomplished in the side passage may be accomplished equally well in the room itself as to air introduced at the ceiling.

Only one point remains to be noticed under this head—the ascent of impurities from the bodies of persons occupying a room. Evaporation from the skin and air breathed from the lungs convey impurity to the air, and cause an ascending movement in the first instance, and it is said that from this cause the descending air may be contaminated before it reaches the person. It is true that air breathed from the lungs is usually warmer than the air of the room, and has an ascending force mainly due to the elasticity of its watery vapor. But its superior temperature is quickly lost, and in accordance with the well-known law of diffusion of gases, it becomes incorporated with the descending air, and passes downward. As some time is necessary to contaminate the air, it follows that in a descending movement all impurity is removed below the region of respiration before it becomes appreciable or injurious: and as the whole air of the room is changed within a period of less than ten minutes, there can be no such accumulation of impurities in any particular section of air as to render it offensive or objectionable. The floors of the galleries being perforated with numerous openings for ventilation, no vitiated air produced there will pass down to the floor of the hall.

The committee has given this elaborate examination to the subject of ventilation by a downward movement of air, not because its approval is indispensable to the plan proposed by the architect, but because it is desirable to adopt a plan which will allow the application of that particular arrangement. The plan will stand good for an upward movement of air through the halls, but, for the reasons already given, sustained by the authorities cited, the downward movement appears to promise the most complete and satisfactory results in ventilating the halls of Congress.

RESUMÉ.

In summing up the whole case upon the architect's plan, it may be stated to involve the elevation of the ceiling, the insertion of side windows, the removal of the glass roof and substitution of a double roof, the separation of the air-space above the ceiling from all communication with the hall, the substitution of fewer lights, with reflectors and ventilating chimneys, for the present lights, the introduction of pure air from an external point by a fan, with proper warming and thorough hydration, and its effectual and regular removal from the hall by an exhausting fan; and, by the plan, either an upward or downward movement of air through the hall may be established; a change from one movement to the other requiring only a change of location in the heating and hydrating apparatus. Upon the merits of the plan, reference is made to the testimony of Mr. Cluskey and the other witnesses, and particularly to the following question and answer in the examination of Dr. Antisell:

"Question. What do you say as to the feasibility and success of Mr. Anderson's whole plan, as compared with the present arrangement?

"Answer. It would be much more effective than the present plan, and feasible in its details."

The evidence of the same witness upon the utility and advantages of an exhausting fan in ventilation is also worthy of particular notice.

THE ESTIMATES.

The concluding subject for examination under the resolution appointing the committee is the cost of the proposed changes. The careful and elaborate estimates laid before the committee, and herewith reported, show a total expenditure for the Senate wing of $113,185 25, independent of an attic, for the erection of which the estimate is $37,500. For the House wing the expenditure is $15,921 30 more. The erection of an attic upon it would cost the same as for the Senate wing, being of the same size. These estimates are made at the present prices for labor and materials, and, as to nearly the the whole proposed outlay, assume the form of proposals by a competent party. Under-written his estimates for the wings, respectively, (including nearly the whole of the work and materials,) Benjamin Severson, the directing engineer in erecting the present ceilings and roofs, proposes to execute a contract at the prices stated, and to give ample security for its performance.

If the plan of improvement now submitted to the two Houses be regarded with favor, the committee recommend that the improvements of the Senate wing be executed between the termination of the present and the commencement of the next session of Congress. There will be ample time for this purpose, and an advantage in concentrating attention and effort upon the one wing. In proceeding, subsequently, to the improvement of the House wing, the temporary roof, fixtures, and implements used in the work upon the Senate wing can be transferred to the other; and any improvement or modification of details in the general plan can be applied in executing the work upon the House wing.

The expenditure for the Senate wing, exclusive of the attic, will fully secure all the changes and improvements proposed in the plan examined by the committee; in other words, will secure the elevation of the ceiling and roof, with side windows and all the arrangements of ventilation. Attics, however, will properly follow the other proposed changes, and are required for architectural effect. Marble, already on hand, can be made available in their construction.

With this question of expenditure upon the proposed improvements, a collateral one, relating to the wings, may be considered. The present plans of the Capitol extensions indicate expensive colonnades upon the north, south, and west sides of the building, to be placed upon the arcades already erected, and an appropriation of $300,000, applicable to their construction, was made at the last session. That appropriation remains unexpended, and the question arises, whether it would not be well to withhold it from the volume of public outlay. There is no necessity for the present expenditure of this large sum, and the utility and advantage of making it, at any time, is matter of debate. Mr. Anderson, in his testimony, says:

"I recommend that you finish these arcades with cornice and balustrade at the top, which will produce a good architectural effect by carrying out the principles of a Roman structure more fully than to finish them as heretofore proposed. It is not intended to put porticoes but colonnades over the arcades. The plan is to carry round the entablature on those colonnades. The effect of it would be simply this: A column before each pilaster has no object of any kind effected by it. It involves an additional expense of marble-work and excessive weight, without any possible advantage. Standing at right angles with the building these columns would not be seen more than the pilasters would which stand by them; they would merely obscure the pilasters, and at the same time deprive the numerous offices on each side of the building of air and light. It is an object in architecture never to introduce an ornament without a purpose. In every well-designed architectural building there never is an ornament introduced that has not its object, which this feature of the design of the Capitol has not. The same observation is applicable to all of the four colonnades—north, south, and two west. * * * A balustrade would be a great deal cheaper than the other plan, and it would, at the same time, admit more air and light."

These views seem to be forcible and just, and are, therefore, brought to the attention of Congress for consideration.

Upon due reflection, the committee are induced to submit the question of withdrawing the appropriation for the colonnades, or at least deferring the expenditure, in view of an inquiry through an appropriate committee as to their utility and merit. If balustrades can be substituted for them without disadvantage, a very large amount of money can be saved to the Treasury, and the burden of the expenditure now proposed by the committee for real and necessary improvements in the Capitol wings be mainly avoided.

ARCHITECT'S REPORT.

To the honorable the Joint Select Committee of the Senate and House of Representatives of the United States on the subject of lighting, heating, ventilating, and the acoustics of the two halls of Congress.

The report of Charles Frederick Anderson, architect and civil engineer, of the city of Washington, D. C., most respectfully represents—

That in obedience to your appointment and directions, made in pursuance of the concurrent resolution of the two Houses of Congress of the 10th of May last, the undersigned has diligently applied himself to a minute examination of the various parts of the north and south extensions, and to the various plans and drawings of their several parts which will necessarily have to be used or which will be slightly affected by the plan by which he proposes to improve the lighting, heating, ventilating, and acoustics of the halls of Congress, with a view to discover the most direct, easy, and economical manner in which the plan can be applied to the structure as it now exists.

This examination has the more strongly and clearly developed the errors of those parties having charge of the construction of these extensions, in departing from the plans which the undersigned had the honor to furnish for the accomplishment of these objects, and which had been submitted to President Fillmore, and been supported by Mr. Webster, then Secretary of State. During the administration of President Pierce, these same plans were submitted to him, and fully examined and approved by Montgomery C. Meigs, then captain of United States Engineers and superintendent of the Capitol extension, and by Professors Bache and Henry, and were also approved by the Secretary of War, under whose direction the works had been placed, as will fully appear by the documents appended to this report; and yet, strange as it may appear, Captain Meigs, in his actual construction of the extensions, not only rejected this plan for the lighting, ventilating, and heating of the legislative halls, but actually reversed the whole system, making the error radical, and therefore more difficult now to remedy or correct. However, by a thorough study and examination of all the parts, the undersigned flatters himself that he has (by his accompanying plans) established the means of making the desired improvements with the least possible alteration or change in the interior arrangements; none, in fact, which will occupy any material apartments or space of the extensions, or injure or interfere with the present appearance and arrangement of the halls of Congress in any way, except to lighten up and greatly improve their interior appearance, as well as the exterior superstructure; all of which will be shown and explained by this report, and by the drawings and plans herewith submitted.

The erroneous plan adopted by Captain Meigs, which has been operating since the occupation of the halls, and now exists in both Houses, receives the exterior air under the ground floor from off the surface of the overheated and dusty terraces, furnishing much of the bad air from beneath, carried to its surface by evaporation and side currents of air from the ground, and this air is also tainted with much of the odors caused by the machinery near which it passes.

The air injured by these causes is drawn to the openings in the cellar or sub-basement walls by the action of the fan-wheel, which forces it up under the floors of the two houses, where it finds vent through the gratings under the members' desks, the risers in the floors, and openings round the halls, and in the galleries. By the action of these currents the vapors introduced from below rise from the floors of the halls, and keep in constant motion the vitiated air generated by the breath of the persons occupying the floors and the galleries, of which carbonic acid gas, being heavier than the purer part of the atmosphere of the chambers, is constantly tending to and settling upon the floors, and would remain upon the floors, like a malaria or noxious miasm, were it not kept in motion near the floor by the currents of dirty air coming up through the gratings and registers; there is added to this bad air all the dust produced by the walking or movements upon the floor, independent of that brought from below. This atmosphere of the halls, as at present arranged, cannot be otherwise than unwholesome, and, were it not for the frequent opening of the doors leading into the halls, would prove much more oppressive and intolerable than it is. To persons of weak lungs, however, the deleterious effects of the present arrangement are more immediate and sooner felt than by persons blessed with more robust constitutions; but even these may be taken sick without any apparent cause, unless it can be traced to the fact that the seeds of the sickness have been unconsciously imbibed while sitting quietly in their seats, and much more so while engaged in speaking, or in the heat of debate, when the lungs must of necessity become inflated and irritated by this pernicious atmosphere.

From these remarks it will be manifest to the plainest understanding that a great error has been committed in attempting to furnish the proper air to the halls, passing it through and mixing it up with the vitiated air as above explained, instead of introducing the pure air into the upper elevation of the halls, and drawing down the im-

pure atmosphere through the gratings in the floor. Having thus simply explained the errors of the present system, it is the purpose of the undersigned to explain the principles and the manner in which he proposes to remedy the existing errors and defects, and furnish to the national councils a pure, temperate, and refreshing atmosphere, of an equal temperature at all seasons, in which members may with safety exercise their lungs while conducting the high and important legislation of the country, with ease and pleasure, and without any apprehension of receiving injury from the medium through which their views, arguments, and business transactions may be expressed in the two Houses.

To accomplish this purpose, the undersigned will endeavor to be as succinct as the nature and the importance of the case will admit of, and, with this view, will divide his explanations as follows, viz:

1st. The undersigned proposes to furnish an abundant supply of fresh, unadulterated air, rarified in winter, hydrated, purified, and cooled down to any desired temperature in summer, to the halls of Congress, so as to insure a uniform temperature at all seasons, with a healthy atmosphere, to be effected by vertical air-shafts to be built on the banks on the west side of the Capitol extension, one for each wing, twenty-five feet high over the level of the flagged terrace, and in the position marked on the accompanying plans of the sub-basement floors, (*specified by the red tint;*) through these shafts pure air, procured from that elevation, will pass into the air-chambers on the sub-basement floors, through dry tunnels, seven feet six inches in diameter, built of hard brick and cement twelve inches thick, and cemented on the inside, so as to make them impervious to damp, with a fall to the vertical shaft, in which shaft a jet of pure water will play at discretion, and be capable of adjustment in the engine-room.

In the sub-basement air-chambers are iron stands on which to pile ice in hot weather, and through which the hydrated and purified air will have to pass to the fan-wheel, which will force it upward through the building in the upper air-chamber arranged outside of the chamber walls, and from which it will pass into the halls of Congress through close air-tight ducts, made of two thicknesses of thin galvanized sheet iron four inches apart, filled in between with crushed pumice stone and liquid cement, passing through the perforations in the ceiling as through a sieve—this perforated portion of the ceiling forming the under side of these air-ducts.

The large upper air-chambers outside of the halls will be arched over with brick and cement, so as to render them impervious to the influence of the exterior atmosphere, either hot or cold, and the air-ducts on the ceiling, which are fed directly from these large air-chambers, are packed on three sides with non-conducting material, as before described, so as to transmit this purified, cooled (or rarified) air to the halls without being sullied by its passage through the atmosphere over the glass ceiling.

The undersigned has arranged four new fan-wheels to carry out his plan, two to force the air up and two to withdraw the vitiated atmosphere from the floors; one for each House. These are so formed as to possess five times the power of the present fan-wheel, but the power is completely under the control of adjustment. The flow of air into the halls may be required, and will be regulated by the speed of the fan-wheel, which depends on the action of the engine.

When very cool air is required in excessive hot weather, we can lower the temperature of the exterior atmosphere to any extent desired, in the halls of Congress, by placing ice in the vertical shaft as well as in the lower air-chambers, and still further by the use of salt with the ice.

All this air passes from the vertical air-shafts through the tunnel, which will be built into and covered up from the effects of the atmosphere by the present bank of earth extending to the basement air-chambers, and from thence up through the building to the upper air-chambers which supply the air-ducts over the ceiling; will be made close, clean, and pure, with a drain built at the bottom leading to the vertical shaft from the lower chamber and the ice cellar, to take off the water introduced by the jet, the melting of the ice, or the rain-water in the vertical shafts.

The undersigned has also annexed the adjoining cellars in each wing (now useless) for stores or ice-houses, where a supply can be kept convenient to the lower air-chambers for daily use when required. In cold weather steam admitted through the cluster of pipes now in use, but placed in the new air-passage, will rarify the air to any temperature required on its passage to the upper air-chamber, through which chamber a stream of pure water will be made to flow, so as to hydrate the heated air before it enters the halls. This can be accomplished by allowing the steam of either warm or cold water (to suit the temperature of the air) to flow over a continuous tray the full length of the upper air-chamber, fitted with a gauze wire bottom and divided into compartments, so as to be able to adjust the amount of mist through which the ascending air will pass at right angles. The temperature of this air, subsequently, will receive additional protection at certain seasons by the admission of air through a register from the upper air-chamber to the space over the glass ceiling, and the influence of the exterior atmosphere will be kept off the glass ceiling by means of a counter-ceiling placed on the back of the iron rafters which support the roof and the ceiling, which rafters it

will be necessary to strengthen to double their present capacity. This counter-ceiling will be composed of crushed or broken pumice stone, filled in with liquid cement, resting on thin corrugated galvanized sheet iron: it will be five inches thick, packed close, made air-tight, and plastered on top with cement. This counter-ceiling will prove to be a non-conductor of heat, cold, or sound from the exterior copper covering of the roof, leaving a space of three feet between the exterior covering and this counter-ceiling.

This plan will effectually prevent the changes in the weather, either by heat, cold, or storms, from affecting the glass ceiling as it does at present, and which has been so much complained of; in fact, the temperature of these halls could never be properly regulated so long as the exterior atmosphere could control the temperature of the space over the glass ceiling, which is at present assimilated to a hot-house in summer and an ice-house in winter, besides transmitting noise from the effects of hail and rain storms, so annoying to the members of both Houses of Congress. It will be only fair to all parties that it should be known that this system of lighting the halls of Congress by means of sky-lights is the only part of Mr. Walter's two designs which has been brought into operation by Captain (now General) Meigs, and which injudicious act is a principal cause of the heated ceilings and bad acoustics.

The undersigned proposes, as an extra or auxiliary means of heating the halls of Congress in very cold weather, to place ornamental benches in the angles of the halls and in the hat-rooms, filled with coils of steam-pipes, to supply additional heat on the floor of each House, which will obviate the necessity for heating the upper current of air too highly to be pleasant.

2. The undersigned proposes to withdraw the vitiated air from the chambers without its remaining above the floors to become injurious to the occupants, and at the same time to regulate and insure good acoustics to both halls of Congress.

To accomplish these objects, the present system will have to be completely reversed, by using the same apertures for withdrawing the vitiated air from the halls of both Houses and from the galleries that are at present used for admitting the air into these apartments, being the registers on the floors, in the galleries, and in the screens which inclose the halls, &c.

This will be accomplished by means of powerful fan-wheels made to work in the passages, which at present admit the air, and in as close proximity as possible to the openings under the floor, through which these fan-wheels will withdraw the vitiated air. The power of these exhausting fan-wheels upon this air can always be regulated to a certainty by their velocity, which will be controlled by the action of the engine.

The current of fresh air passing through the halls downwardly will also be regulated in a great measure by the action of these exhausting wheels, which will regulate the acoustics, as will be made evident from the fact that the voice can no longer ascend to the roof and be lost in the space over the ceiling, as at present. The compressed air forced through the perforations in the ceiling as through a sieve will oblige the voice to remain in the body of each House, it being an axiom in the science of acoustics that glass, next to water, possesses the greatest attraction for sound. The attraction of the voice produced by the glass-paneled ceiling over both the halls of Congress, as at present, will be obviated altogether by the introduction of the imperceptible flow of pure air into each House from the ceiling. As sound always accompanies the current of air, it will be decoyed from the glass ceiling and conveyed into the body of the chambers and into the galleries, as above described, without a reverberation of the voice produced by the present low glass ceiling. The proposed elevation of the glass ceiling, besides improving the architectural proportions of the chambers, will materially assist in establishing good acoustics, as the large field of attraction for the voice will be further removed from the floor, besides being intercepted or arrested on its passage to the ceiling by the incoming flow of pure air through the many apertures in the ceiling, and a greater space will be afforded for the action of that incoming current to mix with the air in the chambers before it reaches the floors. The undersigned recommends that the system heretofore specified in the printed explanations which he furnished to Captain Meigs in 1853 be now adopted for conveying and dispersing the superabundance of sound on the floors to the galleries, and to the reporters' desks in particular, by inserting open slits in the surrounding screen to which will be attached zinc tubes, which will arrest the voice and convey its redundancy from off the floor to the galleries. It will be perceived that by this system the voice cannot escape from the halls in consequence of this plan for admitting the pure air, and by means of these tubes the vibration of the voice or echo will be altogether done away with, so that the full effect of the voice will be rendered more agreeable by this wholesome atmosphere produced by purified and compressed air. It will be seen by the accompanying plans that this change can be effected without interfering with the arrangements on the floors or galleries in either House, or the surrounding corridors, passages, or offices, in any way save by the occupation of one or either of several spaces, the selection of which may well be left to the honorable Committee on the Public Buildings, or any other authority deemed most appropriate, to select a passage

for the pure air from the basement to the upper air-chamber, which can be spared with the least inconvenience; that is, if the passage laid down on the plans for the Senate wing be not approved of. With this exception, it will be perceived by the drawings that this plan for securing good ventilation, &c., interferes with nothing in the halls that can be visible under the level of the cornice of the present ceiling which surrounds the halls of Congress; everything below that level will remain as at present arranged. According to this plan there will be two objects attained: first, to establish what is required by the concurrent resolution; and, second, that it may be effected with as few changes and at as small an expenditure of time and money as is possible. Such a change, however, in the present halls of Congress might be considered cheap at any cost, as it will insure the health of the nation's representatives.

3. This plan will furnish a good and agreeable direct light by day from windows opening on the exterior atmosphere, with a steady, clear gas-light by night, descending through the present glass-paneled ceiling, as elevated, but without the accompanying heat produced by the great number of gas-burners at present distributed all over the ceilings of the two halls of Congress, numbering about one thousand four hundred over the ceiling of the House of Representatives alone, the effect from which renders the heat of the glass and iron ceiling particularly oppressive.

To remedy the present defects, it is proposed to raise the ceilings over the two halls of Congress about sixteen feet, which will produce much better proportioned apartments, as the height of the present ceilings is altogether at variance with architectural rule or the laws which govern architectural proportions. This change, besides improving the architectural appearance of the halls, will afford room to insert a tier of windows extending all around each hall under the cornice and over the gallery doors, as shown by the accompanying longitudinal and cross sections. These windows will be the exact size of the windows in the committee rooms on the basement floors; a direct light will be admitted through the upper half of these side windows, twenty-six in number in the House and twenty-two in the Senate, as well as a borrowed light through seven of the end windows in the Senate chamber, and through nine of the end windows in the House of Representatives. The upper half of the sashes will open on pivots, and when open will admit the air through the halls from the exterior atmosphere, but which will never be required in consequence of a sufficient supply of better air being at all seasons within command by means of the above arrangement; besides, open windows would of necessity damage the acoustics. These windows would be hid from exterior view by the erection of the high parapet, (called an attic in architecture,) on which will be placed the present balustraded battlement, and which is recommended in Senator Foot's report as necessary to relieve the present bad effect of the upper monotonous straight line of the whole building, which is at variance with Roman architecture, (the style of the Capitol building.) The increased elevation of the wings is further called for in consequence of the enormous size of the new dome, (copied from the dome of St. Paul's in London,) the new dome of the Capitol being fully one-third larger than it should be if constructed in accordance with the rules which govern the order of Roman architecture to which the Capitol building belongs. A dome is a prominent ornament to a classic structure, but always subordinate to the proportions and style of the building; but in our case the building is made subordinate to the dome. The published remarks of an educated northern tourist are particularly applicable, when he terms it, "The great dome, with the low buildings beneath, which form the Capitol of the United States." The base of this new dome is actually made to project beyond the front walls of the building, and rest on the projecting portico which forms the principal entrance to the rotunda. To elevate the wings will in some measure disguise this architectural blunder.

Thus it will be perceived that by this one plan two great objects will be effected—better light will be given and better proportions to the halls, and at the same time it will materially improve the exterior architectural appearance of the building. (See accompanying sections and elevations.)

The new windows will be filled in with stained glass, which will produce a soft and agreeable light.

It is proposed to light the Senate chamber at night by means of eight circular burners of Frink's patent, with powerful reflectors, one placed over each; and the House of Representatives with thirteen circular burners, having a reflector over each, by which means the light can be increased to any amount desired, and the present objectionable heat from the great number of unprotected burners on the ceiling will be altogether done away with, as there will be placed over each reflector a copper dome, surmounted by a copper chimney eight inches in diameter, passing out vertically through the roof, which must attract all the heat upward, while it reflects all the light downward; to elucidate which the undersigned submits the accompanying drawings of Frink's patent reflectors, which he would recommend as the best means of lighting the halls of Congress.

The air which this plan introduces through a register from the upper air-chamber into the open space between the glass ceiling and the new counter-ceiling, will increase

the draught upward from the burners under these reflectors and over the glass ceiling, through the flues over the reflectors, which will remove the possibility of communicating any heat from the burners to the glass ceiling, while the counter-ceiling will protect the glass ceiling from the influence of heat or cold from the exterior atmosphere.

The undersigned begs leave to submit a drawing of Reigart's improved fan-wheel, by which he proposes to supply and control the pure air to be furnished to the halls, and to draw the vitiated air therefrom.

He also begs leave to submit specifications and detailed estimates for the construction of the different works more fully described by the plans for the alterations, which he has the honor to submit, in obedience to the instructions of the honorable joint committee.

To remove all apprehension upon the subject, the undersigned would respectfully state that these plans will not interfere with the present condition or appearance of either of the halls below the level of the present glass ceiling, while the arrangements above will establish better architectural proportions, symmetry, and beauty to these halls—a desideratum which he trusts it will not be considered out of place for him to say would have been effected in the original construction of the north and south extensions of the Capitol had his plans been fully and fairly carried out.

Desiring to confine this report to a plain and simple statement of what has been required of him by the joint resolution and the directions of the joint committee, the undersigned has omitted to introduce any reference to the authorities sustaining the principles of the plans which he has the honor to propose; but to aid the judgment and strengthen the opinions of this honorable committee and those of the honorable members of the two Houses, who are so deeply interested in the subject-matter under consideration, he would beg leave to append notes, communications, and reports of high authorities, thereby removing the idea of any presumption on his part of presenting a plan whose principles had not been fully approved by science and practical experience, and which approval the undersigned made himself fully aware of before he submitted his first design, in answer to the published invitation to the architects of the United States, in the year 1850, by practically investigating the different systems for ventilating public buildings in Europe, in particular the Bank of England, the United Service Club House in London, the new British Houses of Parliament, the Millbank Penitentiary, and the Pentonville Model Prison. He investigated the system of ventilation adopted in the two last-mentioned establishments under an order from the home secretary, Sir James Graham—which order will be found recorded in the visitors' book during the summer of 1845—a copy of which could be had upon application in London, which would at once prove his practical experience of this system which he has throughout advocated. Under these circumstances, the undersigned can with confidence assure the honorable committee that there can be no possible doubt as to the result, and it will be possible to successfully carry out the necessary alterations during the interval between the end of the present Congress and the regular annual meeting of the next Congress.

For the more minute and particular explanation of his plan, the undersigned begs leave to submit the following drawings, viz:

Senate Wing.

No. 1.—Plan of sub-basement floor, showing the alterations.
No. 2.—Plan of basement floor, showing the alterations.
No. 3.—Plan of the principal and upper floors, showing the alterations.
No. 4.—Longitudinal section of wing, showing the alterations.
No. 5.—Cross section of wing, showing the additions.
No. 6.—Section showing the vertical air-passage.
No. 7.—Plan of air-ducts over the ceiling.
No. 8.—Front elevation of north wing, showing the attic.
No. 9. Drawing of Reigart's improved fan-wheel.
No. 10. Drawings of Frink's patent reflector.

House of Representatives.

No. 11. Plan of sub-basement floors, showing the alterations.
No. 12. Plan of basement floor, showing the alterations.
No. 13. Plan of principal and gallery floors, showing the alterations.
No. 14. Longitudinal section, showing the additions.
No. 15. Cross section, showing the alterations in roof.
No. 16. Section showing the vertical air-passage.
No. 17. Plan of the air-ducts over the ceiling.
No. 18. Elevation of the south wing, showing the additions.
No. 19. Estimate, &c., from competent parties.

All of which is most respectfully submitted by

CHAS. FRED. ANDERSON,
Architect and Civil Engineer, Washington, D. C.

DECEMBER 5, 1864.

REPORT OF CAPTAIN MEIGS.

OFFICE OF THE EXTENSION OF UNITED STATES CAPITOL,
Washington, May 19, 1853.

DEAR SIR: Having verbally, in my interview with the President and yourself, fully explained the proposed changes, with the aid of large drawings, showing the accommodation to be afforded, it is not necessary here to enter into detail. [*These were the drawings furnished by C. F. Anderson.*]

I will only repeat my own conviction, that the proposed change will secure a better room for speaking and hearing, and better accommodations for the members and officers, and business of the House.

I have prepared some notes upon the application of the general principles of acoustics and ventilation, which have guided me in devising the plan which I propose. They contain the views I expressed to you verbally, and which I propose to write out for submission to some gentlemen of eminent scientific reputation.

While I feel confident that I am correct, I shall be happy to be sustained by their approval if right, and will be much better satisfied to be corrected if wrong, than to be permitted to go on and fail in so important an undertaking.

The changes which I recommend in the plan of the south wing, in order to carry out the above views, are shown upon drawings which have already been explained to you.

I would like to have an opportunity to show them to the gentlemen to whom you will refer these notes.

To lay down general principles correctly is not sufficient security that the application of them will be judiciously made.

I am, sir, very respectfully, your obedient servant,

M. C. MEIGS.
Captain of Engineers in charge of Capitol Extension.

Hon. JEFFERSON DAVIS,
Secretary of War.

Extracts from "Notes on Acoustics and Ventilation with reference to the new halls of Congress," by Captain Meigs, United States Corps of Engineers, May, 1853.

Experience shows that the human voice, under favorable circumstances, is capable of filling a larger space than was ever probably inclosed within the walls of a single room.

If sound be prevented from spreading and losing itself in the air, either by pipe or an extensive flat surface, as a wall or still water, it may be conveyed to a greater distance.

A pure atmosphere being favorable to the speaker's health and strength, will give him greater power of voice and more endurance: thus indirectly improving the hearing by strengthening the source of sound, and also by enabling the hearer to give his attention for a longer period unfatigued.

The common mode of warming and ventilating public rooms is fatal to perfection of hearing.

One or several columns of intensely heated air are introduced through holes in the floor. Being much warmer than the air of the apartment, they immediately rise to the ceiling. If the exit apertures for foul air are above, this fresh and heated air above escapes, having done nothing for the apartment except to cause whirls and currents, such as we see in a column of smoke passing from a chimney on a calm day. The irregular refraction of sound through these currents of equal density tends greatly to produce confusion.

If the exits for foul air are below, the hot air accumulates at the top of the room, and, gradually displacing the cooler air, forces it out through the passages.

Professor Reid relates that he has found the air near the ceiling of a room at the boiling temperature, while those on the floor were complaining of cold.

Here we have a strata of different densities and unequal refractive power, and hence confusion of sound.

As the warmer air must ascend to the top of the room, I propose to let it do so in a large trunk outside of the apartment, pass into a space above the ceiling, and thence, by numerous holes, find its way, as through a sieve, into the room.

By a steam-driven fan, or other mechanical means, we can pump air, in any desired quantity, into any spot into which we choose to direct it.

I would drive all the air required for the supply of the room through a maze of hot-water pipes, raising the whole of it to the temperature desired—60° or 80°, as the case might be.

If the room be 30 feet in height, and it be desired to change all the air in it every fifteen minutes, enough air should be pumped in above to cause a general descent of the whole body of air in the room, at the rate of two feet a minute.

This would be an imperceptible current. The exit should be by numerous holes in the floor, perhaps through the carpet, or the risers of the platforms on which are the members' chairs.

Three important advantages would thus be gained: The avoidance of all eddies, a nearly homogeneous and tranquil atmosphere, and the immediate removal downward of any dust from the carpet, which would thus be prevented from rising, to be inhaled into the lungs.

To prevent the disturbance and contamination of the atmosphere by the gas-lights, I would place them above the glass of the sky-lights—the space between those in the ceiling and those in the roof being separated from the chamber into which the fresh air should be admitted.

In summer the same apparatus which sends in warm air in winter would supply a constant breeze; and, if the temperature of the external air was too high, it might be cooled by jets of water from pipes in the passages, or even by melting ice.

I feel confident that, by observing the above prescribed precautions, we will obtain rooms as near perfection as is possible—"rooms in which no vitiated air shall injure the health of the legislators, and in which the voice from each member's desk shall be easily made audible in all parts of the room." [*This was Mr. Anderson's plan.*]

This was the problem proposed to me for solution.

In conclusion, I have the honor to repeat the request made verbally some days since, that the above notes and observations may be submitted to some persons of scientific reputation, the weight of whose authority may sustain me if I am right, or correct them if wrong.

Respectfully submitted to the honorable Jefferson Davis, Secretary of War, by his obedient servant,

M. C. MEIGS,
Captain of Engineers, in charge of Extension of United States Capitol and Washington Aqueduct.

Subsequently, the subject having been referred to Professors Bache and Henry, those gentlemen addressed a communication to the Secretary of War as follows:

SIR: The undersigned have examined, as you requested, the principles proposed by Captain M. C. Meigs, of the Corps of Engineers, with reference to the acoustics, heating, and ventilation of the hall of Representatives.

They are now prepared to report that the principles presented to them by Captain Meigs are correct, and that they are judiciously applied.

They are of opinion that the plans should be provisionally adopted, in order that the building may not be delayed, subject to such modifications in the details as may result from the further study of them by Captain Meigs, or from the experiments and observations of the commission.

This general adaptation of the plans will not, it is believed, interfere with any changes of details likely to be found desirable.

Very respectfully, yours,

A. D. BACHE.
JOSEPH HENRY

Hon. JEFFERSON DAVIS,
Secretary of War.

ESTIMATES.

Senate chamber—abstract estimate.

Altering roof and raising ceiling, &c	$27,979 20
Scaffolding and machinery for all work	10,000 00
Brick-work in raising the chamber walls	11,929 05
Air-ducts over the ceiling, two thicknesses	5,593 00
New windows round Senate chamber	3,600 00
Belt course under the windows	784 00
Gutters and eve cornice	3,700 00
Remodelling flank roof and gutters	5,000 00
Workmanship on attic walls and balustrade	37,500 00
Mason's work in alterations air-shaft and tunnel	20,000 00
New steam-engine	2,000 00
Two new fan-wheels	3,000 00

Eight reflectors, fixing, and pipes	$9,600 00
Rearranging, rarefying steam-pipes, &c	5,000 00
Lining upper air-chamber so as to make it water-proof, with hot and cold water-pipes and sieve the entire length	5,000 00
	150,685 25

The above calculations are made at the present prices for labor and materials.

CHARLES F. ANDERSON,
Architect and Civil Engineer.

Hall of Representatives—abstract estimate.

Altering roof and raising the ceiling, &c	$38,970 10
Raising the brick walls round the hall	13,925 45
New windows round the hall	4,400 00
New belt course under windows	928 00
Air-ducts over ceiling, two thicknesses	6,783 00
Gutters and eave cornice	4,500 00
Remodelling flank roof and gutters	6,000 00
Workmanship on attic wall and balustrade	37,500 00
Alterations in mason's work, air-shaft, and tunnel	15,000 00
A new steam-engine	2,000 00
Two new powerful fan-wheels	3,000 00
Thirteen reflectors, including fitting and pipes, &c	15,600 00
Rearranging, rarefying steam-pipes, &c	3,000 00
Lining upper air-chamber so as to make it water-proof, with hot and cold water-pipes and sieve	5,000 00
Scaffolding and machinery	10,000 000
	166,606 55

The above calculations are made at the present prices for labor and materials.

CHARLES F. ANDERSON,
Architect and Civil Engineer.

Estimates and proposals for altering and raising the roofs and ceilings of the Senate chamber and hall of Representatives; the brick walls surrounding these apartments, and the windows within these walls; the large air-chambers with their water arrangements; the air-ducts over the ceilings, and the workmanship of covering the roofs complete; also all necessary scaffolding, and temporary roofing for protecting the interior of these chambers during the progress of the work: all to be done substantially, in a workmanlike manner, and completed in strict accordance with the plans and printed specifications prepared by C. F. Anderson, architect, and subject to his approval.

In altering these roofs, it is proposed to use the main ties in their present form, as these are known to be composed of excellent material, and to have been tested to the extent of ten thousand pounds strain to the square inch of cross section; but the rafters and braces will be altered, and made to conform to the improved roofs, and there will be seven-eighths added to the size of the rafters, so as to give to them a cross section of fifteen square inches—seven inches more than the old rafters have. This will make their strength *practically* equal to that of the ties with which they are connected, which is not the case with the old rafters; having only eight inches in cross section.

The engineer of the old roofs made a grave mistake in making the sizes of the ties and rafters nearly equal. He seems to have acted upon the theory that, as the tensive strains in the ties and the pressure in the rafters are about equal in magnitude, and as it is known to require about equal magnitudes of positive and negative forces to crush wrought iron by pressure, and to tear it asunder by tension, that therefore the sizes of the rafters and the ties must also be equal to give to them corresponding strength. But he seems not to have considered the facts developed in practice, that rafters formed and acted upon as in these roofs, will fail by lateral deflection under much less pressure than is required to *crush* the material of which they are composed, and that the corresponding amount of tension due to the ties cannot, by deflection or distortion of any kind, impair their normal strength. Therefore though *theoretically* right as to the magnitude of the forces acting in opposite directions in the rafters and in the ties, yet, in not providing for the difference in their effects, has resulted in *unscientific* construction, in roofs that have, practically, not more than half the strength that theory assigns to

them. This error will be obviated in the proposed roofs by adding seven-eighths to the size of the rafters, while the ties remain unchanged.

For the purpose of ascertaining to what amount of strains the parts of the modified roofs may be subjected, and thereby determine the sizes and strength required for each part, I have made a computation of the weight of the roofs, with the ceilings, and such other parts as will be sustained by the roofs: and I find these to be equal to 53 pounds to each square foot of horizontal surface covered, to which I add ten pounds to the foot for possible loads of snow—total, 63 pounds to the foot. This is a large allowance for snow in this climate, and the high and open position of these roofs will preclude the possibility of drifts collecting upon them. The roofs, thus loaded, will produce tensive strains in the ties equal to 8,784 pounds to the square inch of cross section, and 4,685 1-15 pounds pressure to the square inch in the rafters; which is only about one-seventh of the ultimate strength of good iron. The other parts will be similarly proportioned as to size of parts of the strains.

SENATE CHAMBER.

Altering roof, raising it, and the ceiling, as per plan	$27,979 20
Gutters and eave-cornice round the raised roof	3,700 00
Brick walls around chamber, as per plan	11,929 05
Scaffolding and temporary roofing so as to protect the old work	10,000 00
Remodelling flank roofs and gutters, as per plan	5,000 00
Lining upper air-chamber, so as to make it water-tight, with hot and cold pipes, and sieves	5,000 00
Air-ducts over ceiling, two thicknesses	5,593 00
New windows around the chamber, as per plan	3,600 00
Belt course under these windows, as per plan	784 00
Mason work in tunnel and in new air-shaft	20,000 00
Rearranging rarefying steam-pipes, &c	5,000 00
Work on attic walls and balustrade	37,500 00
	136,085 25

I will execute this work, as above set forth, for the sum of $136,085 25, and will give ample security for the due performance thereof.

BENJAMIN SEVERSON, 359 *E street.*

WASHINGTON, *December* 2, 1864.

HALL OF REPRESENTATIVES.

Altering roof, raising it and the ceiling	$38,970 10
Gutters and eave-cornice round the raised roof	4,500 00
Brick wall around the hall, as per plan	13,925 45
Scaffolding and temporary roofing for protection	10,000 00
Remodelling flank roof and gutters, as per plan	6,000 00
Lining upper air-chamber so as to make it water-tight, with hot and cold water pipes, and sieves	5,000 00
Air-ducts over ceiling, two thicknesses	6,783 00
New windows around the hall, as per section	4,400 00
Belt course under these windows, as per section	928 00
Mason work in tunnel, and air-shafts, also alterations	15,000 00
Rearranging rarefying steam-pipes, &c	3,000 00
Work on attic walls and balustrade	37,500 00
	146,006 55

I will execute this work as above set forth for the sum of $146,006 55, and will give ample security for the due performance thereof.

BENJAMIN SEVERSON, 359 *E Street.*

WASHINGTON, *December* 2, 1864.

NOTE.—While these pages are going through the press, the attention of the committee is directed to an elaborate report upon ventilation by Messrs. Shedd and Edson, civil engineers, to a committee of the Massachusetts house of representatives, dated January 1, 1865. Copious extracts from this valuable paper are given in the succeeding pages, upon the questions of moisture in the air and the downward movement in ventilation. The views presented by this committee in the foregoing report receive in

those extracts an intelligent and weighty indorsement. The actual and successful application of the downward movement by General Morin in the hall of the Conservatory of Arts and Trades, and by Mr. Gurney in the houses of Parliament, and in court-houses and other public buildings in England, must be regarded as satisfactory and decisive in favor of the conclusion to which the committee have arrived. In fact, the current of authority at this time, as well as sound reason, is for the proposed plan.

Extracts from the report on ventilation of J. Herbert Shedd and William Edson, esquires, civil engineers, made to a committee of the Massachusetts house of representatives, Boston, January 1, 1865.

MOISTURE IN AIR.

Scientific and medical authorities generally concur in the opinion that in-door air after heating, should contain nearly the same proportion of moisture as the average of out-door air of the same temperature; but when air is brought in from out of doors at a temperature of zero, and raised by heaters to 68°, it would require the addition of of $4\frac{348}{1000}$ grains of water per cubic foot of air to bring it up to the required degree of moisture. For the proper moistening then of fresh warmed air introduced at the rate of twenty cubic feet a minute for each one of three hundred persons two hours, the air taken at zero and at the average degree of moisture, no less than fifty-nine gallons of water would require to be added.

* * * * * * * * * *

Exactly how much vapor, or what per cent. of moisture, is the most healthy, has not yet been determined. From much observation, we have taken 65 per cent. of saturation as the amount most likely to prove healthy.

The mean relative humidity of the air at Philadelphia for the year 1863 was 67.2, and the mean annual average for twelve years, 68.5.

THE DOWNWARD MOVEMENT.

The essential point of ventilation is constant change of air, the removal of the air that becomes laden with the secretions of the body, and its replacement by fresh air. In nature this change is generally effected by currents of wind that rapidly sweep away and renew the air. In addition, according as the air is cooler than the body, the portion coming in contact with the person is warmed, and, becoming lighter than the rest, has a tendency to rise and give place to new air. This tendency is shown by a sensitive wind-wheel, in low temperatures, at the distance of a few inches from the body.

The heat of the breath also has been assumed to be the special provision for its removal and replacement with fresh air. This has been a favorite theory even among scientific men. Mr. Gurney was one of the first to stoutly deny the fact; in his testimony before committees of Parliament in 1854, he asserted that the downward propulsion which the breath received by the position and direction of the nostrils did not cease, so far as the impurities with which it is laden are concerned, till it deposited them on the ground. We have not been able to verify Mr. Gurney's assertion, that on a frosty day the vapor from a person's mouth may be seen to describe a parabolic curve to the ground; but any one may see the vapor of the breath driven from the nostrils taking at first a downward course. A breath of fair strength, with the thermometer near the freezing point, may be seen by its condensed vapor, driven downward and slightly outward, for a foot or more. The subjoined sketch is an accurate representation of the visible breath seen in air of 26° Fahrenheit, the rate of breathing being twenty-one to twenty-two times a minute. [The figures omitted.]

In this observation, the wind-wheel moved rapidly near the body, and steadily at a distance of six inches in front, and also at two feet above the head. Notwithstanding this upward current, the breath was strongly marked by the condensed moisture, fourteen inches below the nostrils, and would doubtless have been seen further down but for the dissipation of the moisture. In a room with the air at 65°, the same wind-wheel was in motion close to the vital parts of the body, but stopped entirely at two or three inches distance from the body, or above the head. This was to be anticipated, because the force that carries the wheel is the rising of the air in consequence of its greater heat and lightness than that of the surrounding air, and is proportioned to the difference of temperature.

In order to determine the amount of heat operating to cause the air to rise, a thermometer was placed within the clothing near the vital parts of the body, where it was found to stand at 82°, while the person remained in air at 65°; on going into air at 20°, with additional clothing, the thermometer stood at 76°. The air around the body in a warm room, therefore, would rise with a force not far from 17°, while in outer air at

20° it would rise with a force not far from 56°. In point of fact, we suppose the air would rise with a velocity somewhat less than these figures, but, relatively, we think they are nearly correct. A more sensitive instrument would have been affected at a greater distance, but the same wheel showed a distinct downward motion of the breath 15 inches below the nostrils, in opposition to all the rising tendency, by reason of the warmth of the breath and of the air about the body; and this motion also would have been shown to a greater distance by a more sensitive wheel.

Let us now suppose, to be well within bounds, the breath to be moved 12 inches below the face. The downward motion having ceased, the upward motion should then begin which is to carry the breath up out of the way. This old breath has about one second in which to rise, from rest or reverse motion, more than 12 inches, in order to be out of the way at the next inhalation. The difference of temperature necessary to give the breath this movement of 12 inches in the first second, if the breath rises by heat alone, will surprise any one not familiar with such calculations. It is not less than 180°; that is to say, the breath, in order to start from rest and rise 12 inches in one second through air at 65°, would have to be at a temperature of 245°.

The absurdity to which this calculation and experiment reduce the idea that our breath is carried away from the face by its upward tendency from heat, is increased by the observation, which every one may make, that a thermometer at 65° cannot be raised more than 1° by breathing upon it at 9 inches distance, and that at 10 inches no effect can be perceived. But the upward tendency of the breath is doubtless much increased from the diffusion and lightness of its aqueous vapor, and possibly from other causes, though, under the most favorable circumstances, all causes combined are not sufficient to carry the expired breath up out of the way before another inhalation, as may be seen on a frosty day; and it is evident to all that the air contaminated by the body, if carried upward, must in some measure be inhaled.

The fact, then, in regard to the removal of the expired air from the face is rather the reverse of the theory that it is carried upward out of the way. It is carried downward at ordinary temperatures with force, as of a steam-jet, that, for aught we know, deposits it with its impurities, as Mr. Gurney says, at the floor. Though we have not traced its descent more than a third of the distance, a calculation of its downward impulse shows it to be sufficient to overcome all the upward tendency of its own heat, and that of the air about the body to a considerably greater distance than that of the floor. The supply of fresh air for inhalation comes in from above and about the face, to supply the partial vacuum created by the downward jet; and in this jet, as Mr. Gurney has pointed out, not in the upward tendency of the warm breath, is the admirable provision of nature for carrying away the expelled air before more is to be inhaled.

We are not, however, to conclude that the rising force imparted to the air about a person, by heat of skin and lungs, is absolutely nothing, although in warm rooms it is practically of small account. More heat is given off from the body by radiation than by contact of air. Inclose a person in a non-conducting cylinder not much above his size, and the accumulation of heat about him would give some force to the air. And so, in an assembly, the heat accumulated around and among the persons gives the air a certain amount of rising force. Taking for a basis Péclet's estimate of the amount of heat given off by an individual in moderate temperature, the upward force given to air by three hundred persons in an hour would be equal to the power of five pounds of coal. This is an extreme outside calculation of the force of the heat imparted by the body. If the usual deductions should be made for the wasteful manner of this application of heat to raise the air, less than half this amount of coal would be seen to balance the elevating effect on the air of three hundred persons.

Yet, on the assumption of an effective lifting power in the heat given off from the body has been based the prevailing system of ventilation—that is, of taking the fresh air in at the bottom of the room and the foul air out at the top. This is claimed to be the natural system, and, therefore, the cheapest and best. The claim is admissible in cases where no power exists to change the air except this slight difference of temperature; but what becomes of it in cases where tons of coal are burned a day for the sole purpose of producing a power to move the air, and where, as is common, all the air taken out at the top is brought down again in pipes to the ground before being sent off through a chimney shaft? Is it not more natural, cheaper, and better to go on as nature begins, and take the foul air of breath and body directly down through the floor to its exhausting chimney?

These two theories of ventilation have been often argued and both practiced with varying success. We will consider the circumstances of a large hall of assembly, and show the operation of the two systems.

We must suppose a floor well packed with people, at the bottom of a cubical or hemispherical hall: suppose them to have entered at once, the hall being previously filled with pure air: directly the whole lower stratum of air, in which the audience are, is contaminated by their exhalations and emanations. Now, the problem is to get that stratum of air out of the hall before any of it can come to use again, and to replace it with fresh air of the right temperature. It is obvious that it cannot be taken out side-

ways, because then many would have to breathe over again the breath of others. It can be taken only either up or down. If it is taken up, the fresh air that is to supply its place must enter at the floor from which the foul air rises, for no air will leave a spot till other air is ready to fill its place. In order then to lift the whole of the foul air bodily from the floor, it is necessary that the whole floor should be open for the admission of fresh air. Wherever there is a piece of solid floor through which the air cannot pass, there will be a dead space of foul air above it, which will not rise with the rest, but will remain to be gradually mixed with the fresh air entering around it. If the dead space is considerable, the whole amount of air required must enter in the limited space of the openings, and the velocity must be proportionately increased. According as this space is reduced and the velocity increased, the air entering has a force that carries it up beyond the place where it is to be used, and mixes it with the foul air passing off; a part of which mixture will return in counter-currents and gradually replace the air in the dead spaces. The operation may be seen by a simple experiment.

Take a bucket-full of turbid water and lower it into a tub of clear water of equal temperature and density. If the bottom of the bucket could be removed without disturbance, the sides might be lowered gently and the clear water would replace the turbid water in the bucket completely, without much mixing. So, too, if the bottom of the bucket is entirely perforated, leaving very slender partitions between the perforations, the clear water may replace the turbid with little disturbance and mixing. But if the perforations are limited to holes of, say, half the space in the bottom, on pushing down the bucket the clear water will rush up into the midst of the turbid water, and the turbid water on the solid spaces of the bottom will remain, till, mixed by friction and counter-currents with the pure water, it is gradually carried up. The fewer and smaller the holes the longer the turbid water will remain in the dead spaces; and if its turbidness is from a constant source, it will be likely to increase rather than diminish.

Dr. Reid, the most scientific and experienced, perhaps, of the advocates of the upward system, seeing this necessity for introducing his fresh air through the whole extent of the floor, when, after experience in the temporary houses of Parliament, he was called upon to arrange the ventilation of the new House of Commons in Westminster palace, had the entire floor made of perforated iron. This was afterward covered with haircloth carpeting, and through nearly its whole extent the fresh air was admitted. No expense was spared, and the system was tried for some years under the most favorable circumstances. The result was that on account of the raising of dust by the entering air, and still more on account of the uncomfortable draughts brought up against the honorable members' legs, nine-tenths of the floor came to be covered with sheet lead under the carpet. And when the entrance for fresh air was thus limited, it being through the carpet but a fraction of the nominal extent, complaints became so loud both of strong currents and of foulness of air that the whole matter of ventilation was turned over to Mr. Goldsworthy Gurney, who undertook it on the opposite system of introducing the fresh air above and taking out the foul air at the floor.

In the French Senate chamber, formerly supplied with fresh air through the rising steps behind the members' seats, these openings were closed because of the draughts about the senators' legs, and, according to Morin, in 1862, they had no ventilation at all.

Such are some of the difficulties of changing the air of a crowded hall by introducing it at the bottom and taking it out at the top. To avoid them, Sir Charles Barry, the architect of the new houses of Parliament, introduced his main supply of fresh air in the House of Lords through the middle compartment of the ceiling, expecting it to descend to the floor, then to rise at the sides, and to be taken out in the side compartments of the ceiling. This was expecting too much of atmospheric nature, and, after a few years' trial, this hall, too, was given over to Mr. Gurney, who proposed to take the air out at the floor. We shall not dwell on the system of taking both the fresh air in and the foul air out at the top, or on that of taking the fresh air in and the foul air out at the bottom, because these systems, to be equally effectual, must double the amount of current that would be caused by taking the air in one way and out the other, and are for that reason not to be recommended for large halls, where the great difficulty is to change the air fast enough without making unpleasant currents.

Introducing the air at the upper part of a hall and taking it out at the bottom, known as downward ventilation, has certain obvious advantages: 1. It takes the emanations of the skin and lungs out of the room immediately after they are given off, before they have a chance to be inhaled. 2. Consequently, the fresh air coming unimpaired directly to the heads of the audience, a much less supply is required to secure the freshness of what is inhaled than is necessary when the air is brought first to the feet or becomes mixed with foul currents. 3. The warm air introduced has the opportunity of spending something of its heat on the ceiling and walls before it comes to be breathed, instead of being breathed at its highest temperature. 4. The fresh air is diffused over the whole area of the hall, even if introduced through few apertures,

before reaching the audience; by which means the air is brought upon them more gently than if it came directly upon them through limited apertures. The greater the number and area of apertures for the exit of the foul air at the floor, the better, and the less will the current be felt. But this current, being downward, will always be felt in a much less degree than a similar current upward about the legs, for obvious reasons; and the dust and odors of the floor will be carried down instead of up into the air to be breathed.

For illustration of downward ventilation, take, as before, a bucket of water, turbid near the bottom, and sink it in a tub of clear water. Suppose the bottom to be well perforated, or even but partially so, clear water coming in at the top, as the bucket is raised, will force out the turbid water very effectually at the bottom, whatever may be the position of the openings at the top. In other words, air passing through a room will drive out more thoroughly and uniformly the air at the side at which it goes out than that at the side it enters.

The gain effected by bringing the fresh air to the face, to be breathed before it sweeps the body, is quite important. It may be estimated by considering how much less supply of fresh air would be sufficient for a man inclosed in a cylinder just large enough to hold him, in case the air came down to his head first, than in case it came to his feet first, and up by his body to the face. A crowded assembly may be considered as a set of such cylinders, closely packed together, with their occupants like bees in their cells. The great advantage, in point of economy of freshness, of sending the air downward, instead of upward, is here very apparent; and it is obvious that in the one case may be obtained perfect purity of the air, while in the other it can never be more than an approximation.

The heating of the walls, ceiling, floor, and furniture of a hall is of great importance. Otherwise, very hot air will not suffice to keep the occupants comfortable. If, as in most cases, this heating is to be done by the warm air alone, the more there is accomplished before the air is breathed the less will be the comparative heat of the air entering the lungs.

This we consider in itself a decided advantage, and it is obtained in greater degree when the warm air is introduced above than when it enters at many points through the floor.

When the air is introduced at the top of a hall and drawn out at the bottom, it is rapidly diffused through the whole upper space, and then begins to descend slowly and very uniformly to the floor. This is the case even at present in our Representatives' hall, where the warm air enters at a single opening above the Speaker's chair. This air rises at once into the dome of the hall, as seen by experimental balloons, where it is quickly diffused, and then descends almost vertically in all parts of the hall to the floor. This arrangement, though designed only as a temporary and experimental step to the still better plan of introducing the air directly into the dome, proves, in a degree, that much greater gentleness and uniformity of motion, with freedom from needless currents, may be obtained with downward ventilation than it is possible to have with upward ventilation; for, in the latter, the rising air can occupy but very much less space, must have, at the level of the audience, proportionally greater velocity, and must alternate with additional counter-currents.

The objections to the downward system are: 1. Its supposed antagonism to the natural laws of upward movement of heated air. 2. The supposed greater heat of the upper air in the hall under that system.

The first objection we have already sufficiently considered. Practically, even those who favor upward ventilation admit that there is no difficulty in taking the foul air out at the bottom by the application of a moderate force; and nothing in the art of ventilation is more universally admitted than the necessity, under any form of ventilation, in all public buildings, for the employment of some special power.

Nor is the objection strengthened materially by the common impression of greater foulness at the top than at the bottom of a crowded room. There is some truth in this impression in regard to rooms which have no ventilation, though most careful experiments by eminent chemists fail to show any considerable or uniform increase in carbonic acid in the upper part of crowded halls; perhaps as many experiments have shown the greater amount at the bottom as have shown it at the top. What slight increase there may sometimes be at the hottest state, is probably more than lost as the heated carbonic acid cools, and, to some extent, sinks from its weight. Sensitive observers, too, have found that though the upper portion of a heated, ill-ventilated hall smells most offensively, and, from its heat, is oppressive, the lower portion most seriously affects their state of health. In our Representatives hall there has been the most serious complaint of oppression on the lowest portion of the floor, around the Speaker's desk. In point of fact, we believe, the idea of the greater foulness of air at the top arises mainly from crowded evening assemblies, where the heated products of combustion from gas-lights contaminate the upper air to a great extent.

It is of the utmost consequence that these products should have some direct means of removal. This is provided for in the best ventilated halls by so disposing the gas-

burners that they may have direct and independent outlets for their smoke and gas. Another obvious explanation of the frequent greater impurity of the upper air in crowded, ill-ventilated halls is that, without special force of supply, there is always a rush of fresh air into the hall through the doors as they are frequently opened; this air being cooler, of course, forces the warm foul air upward. After all, the greater heat at the top of the room is probably the chief cause of the impression of greater foulness, though with the heat may be associated some light odorous gases. But all this is of no importance against systematic downward ventilation. When the foul air is taken off at the bottom, it is no longer found in excess at the top.

Morin's very accurate experiments in the smaller hall of the Conservatory of Arts and Trades, ventilated from above downward, show, on the average, a scarcely perceptible difference between the temperature of the air above and that below. In our own Representatives hall, where now the warm air is introduced thirteen feet above the Speaker's platform, and the foul air taken out at the floor, though the arrangements for supply and exhaust are, at present, quite limited and much less than we should desire, we have found as the average of over five hundred observations in eighty-six different positions, with the exhaust ducts open, the temperature opposite the gas-burners above the gallery only about two and one-half degrees above the average throughout the hall; while that of the lower seats was not two and one-half degrees below the average. When, however, in the midst of these observations, the exhaust ducts were temporarily closed, the difference soon doubled, though the whole average temperature was slightly lowered.

To give these results more in detail:

Observations in level planes.	Ventilating ducts.	
	Open.	Closed.
Average in dome of hall	78°.5	85°
Average opposite gas-lights above gallery	71°.46	73°.54
Average opposite gas-lights below gallery	68°.57	66°.50
Average in the seats	66°.63	63°.72
Average throughout the hall	68°.86	68°.17

It is essential to the system of downward ventilation, as well as to all other systems, that a constant current should be maintained by keeping the inlet and outlet always open. When less heat is desired, the change must be effected, not by stopping the warm-air inlet, but by letting into it cooler air. And when the heat of the room goes off too fast, especially when it is empty, the heat may be economized by letting the air at the floor back into the heating chamber instead of out of doors.

In support of the downward system we will only refer to Mr. Goldsworthy Gurney's testimony before the committees of both houses of Parliament who has for the last ten years had charge of the ventilation of the houses of Parliament, and who has introduced the downward system with great success in court-houses and other public buildings in England; to the book of Mr. Ruttan, of Canada, who has introduced the system most successfully in railway cars, on some of our roads, as well as in buildings; and to the conclusions of General Morin, well known for his valuable scientific works on different departments of engineering, and the author of the latest and most elaborate work on ventilation, (Études sur la Ventilation, Paris, 1863, 2 vols., 8vo., pp. 1017.)

General Morin says, in treating of the ventilation of large halls:

"The numerous observations which I have gathered, and which any one may repeat, have shown me, as I have already said, that there are very sensible inconveniences in making the new air, warm or cold, enter near the occupants of a hall.

"This air is always necessarily at a temperature different from that of the hall; warmer, if it is desired to raise or even sometimes to maintain the inside temperature, as is the case in winter, to compensate the cooling effect of the walls, and when there are few present; and, on the other hand, cooler, if the outer temperature is somewhat high, and if there are many occupants.

"In the one case, as in the other, the neighborhood of the apertures for the entrance of air is disagreeable, and, whatever care is taken to limit the velocity by giving the apertures the greatest possible extent, it is seldom that the velocity can be less than 1.3 to 1.7 feet per second, from which there is sometimes an uncomfortable sensation."

After referring to the experience in the English House of Commons, and to that in the French Senate chamber, in both of which the apertures for the admission of air had been gradually closed, because of the objectionable currents, till ventilation had almost ceased, General Morin continues:

"It does not seem to me, then, suitable for amphitheaters, or for any other place of

a similar kind, to admit the new air through the floor, by the steps or the step-risers. On the contrary, here as elsewhere, the air should be made to enter as far as possible from the audience; and as it may be often necessary the same day, and from time to time, to vary the temperature of the air admitted, within certain limits, arrangements must be adopted which will render the mixing of warm and cold air as complete and as easy to modify as possible, before it comes in contact with the audience. This, it must be said, is the most delicate condition to well fulfill, and amphitheaters are, perhaps, the case in which the difficulty is presented in the highest degree.

"After having reflected much and observed well the various effects of the introduction and evacuation of the air, this is the solution which has seemed to me the surest, and which I have settled upon for the amphitheaters of the Conservatory of Arts and Trades. It has already been applied to one of them as completely as the local conditions would permit in a building of old construction. The vitiated air being that which it is necessary to draw out, it is desirable to hinder it from diffusing in the hall, and consequently to extract it at the spot where it is vitiated, that is to say, as near as possible to the individual occupants, through perforations in the risers, or backs of the steps, in order to make it pass out under the amphitheater.

"The introduction of fresh air presents two principal phases, quite distinct.

"In the first, which precedes the arrival of the people, the amphitheater should be brought up to a moderate temperature, which may, however, be raised to 64°.4. At this moment it is evident that the movement of air from inside to outside of the hall should be, in general, completely interrupted; and in order that there may be established throughout the hall a suitable temperature, it seems natural to allow the warm air to be introduced then by passages communicating with the heaters and opening through the floor at the lowest points.

"In the second period, on the contrary, soon after the entrance of the audience, and according to their number, more or less, we must extract a portion of the air now vitiated and more or less heated, and replace it with pure air. But this fresh air would be, as is daily observed, very uncomfortable if its temperature were much lower than that of the air of the hall, and especially if it flowed in too near the audience.

"From this results: 1. The necessity of introducing the fresh air first into a receiver, which we call the mixing chamber, where, by the simultaneous entrance of hot air and cool air, in proportions which can be easily regulated, the means are kept of admitting into the hall only air of the desired temperature. 2. The obligation, not less imperative, to place the openings for the admission of this fresh air as far as possible from the audience—that is to say, about the ceiling of the amphitheater, if the circumstances of the place permit, or at least at a considerable height. In general, whenever the construction will permit, it is preferable to bring the fresh air through the ceiling or the cornice by openings so proportioned that the mean velocity of the air will not exceed 1.3 to 1.7 feet per second."

The general rules adopted by Morin are as follows:

"1. Place the exhaust orifices as near the points where the air is vitiated as possible.

"2. Have as many orifices of exhaustion as the construction of the building will admit of.

"3. Orifices of exhaustion should be so proportioned that the velocity of air passing through them may be from 2.6 to 3.3 feet per second.

"4. Unite the different groups only by entering them into the common conduit, or into the chimney of exhaust, and as far as possible from their openings into the rooms. Arrange in such a manner that they can be easily examined and repaired. Protect from cold.

"Do not place the orifices for the entrance of fresh air near the floor: it is proved, in the French Senate, that where the orifices were near the floor, currents of *warm* air, having a velocity of from 1.3 to 1.7 feet per second, were disagreeable: currents of cold air should be avoided for much stronger reasons.

"The above is agreeable to the conclusions of both French and English engineers."

The whole discussion of the matter of ventilation before committees of Parliament for twenty years, ending some ten years ago, is full of interest and instruction: through it all Mr. Gurney appears in behalf of downward ventilation, in opposition to Dr. Reid, who, for that time, was attempting to ventilate the houses of Parliament satisfactorily on the upward system. When, in 1854–'55, the committees of both houses determined to give their ventilation into the hands of Mr. Gurney, they seem to have adopted the conclusion of Mr. Robert Stephenson, who, himself a member, was examined by a committee of the House of Commons in 1852, and testified that for a crowded hall he preferred downward ventilation, unless the gas-light should interfere; and that it was as easy to draw the air out downward as upward.

Dr. Morrill Wyman, whose little treatise on ventilation contains more scientific and sensible information on the subject than almost any other book in the English language, though he gives assent to the prevailing theory of upward ventilation, says:

"There is no impossibility, however, of producing a constant and equable downward movement, which shall also effectually prevent all respired air from being again pre-

sented to the organs of respiration. The first movement of expired air is from the mouth, horizontally, and from the nostrils, downward, before it begins to rise; consequently, a downward current may, without much difficulty, be brought to bear upon and remove it."

As regards the manner of applying power to effect the change of air, it is sometimes applied to the exhaustion of the foul air, and sometimes to the supply of fresh air. Either way is effectual in a degree, but neither alone accomplishes quite all that is to be desired. Forcing the fresh air in abundantly will drive out the air already in the hall at every outlet, and it is essential for security against the intrusion of cold currents through cracks and doorways. But it will drive the air out mainly at the easiest outlets, and some of the most important may be neglected, because of being out of the easiest way for the air to pass. The only sure way to get the air out just where you want it to go out is to apply an exhausting force at the outlets, to guide and assist the expelling force. The filling method is called the plenum method, and the exhausting the vacuum method. Much has been said about the superiority, for working vigor, of air in a plenum, or over-pressure condition. There is no doubt of the fact that under a high atmospheric pressure a man has greater power than under a low pressure. But the amount of superior pressure that can be obtained in a common hall is very slight, and can hardly have a perceptible effect. A nearly even balance of the filling and exhausting forces, making the in-door barometer about the same as the out-door, but with the filling force enough in excess to keep out all air seeking to enter without leave, is the most economical and satisfactory condition to obtain.

WARMING AND VENTILATING THE CAPITOL.

Letter from the Secretary of the Interior, in answer to a resolution of the House of the 4th instant, transmitting a report of T. U. Walter relative to warming and ventilating both houses of Congress.

DEPARTMENT OF THE INTERIOR,
Washington, D. C., May 7, 1866.

SIR: I have the honor to acknowledge the receipt of the resolution adopted by the House of Representatives on the 4th instant, directing the Secretary of the Interior to communicate to the House the report made to him by Thomas U. Walter, late Architect of the Capitol Extension, on the warming and ventilation of the two houses of Congress, with the reports of Professor Joseph Henry and Dr. Charles M. Wetherill, accompanying the same.

In compliance with the resolution, I transmit herewith a communication on the subject to which it refers, addressed to me on the 4th instant by Mr. Walter, and the papers accompanying the same.

I am not aware that Mr. Walter, during his official connection with this Department, made any report in relation to warming and ventilating the Capitol. The papers now sent are, it is presumed, those called for by the House.

I am, sir, very respectfully, your obedient servant,

JAS. HARLAN, *Secretary*.

Hon. EDWARD MCPHERSON,
Clerk of the House of Representatives.

REPORT ON THE WARMING AND VENTILATING OF THE UNITED STATES CAPITOL, BY THOMAS U. WALTER, ARCHITECT.

WASHINGTON, D. C., *May* 4, 1866.

SIR: During the last session of Congress it was deemed expedient to institute a series of experiments to ascertain, by accurate scientific tests, the actual results of the means employed for warming and ventilating the United States Capitol extension; and, in order to render the proposed investigation entirely reliable, and to secure its accomplishment in accordance with the most recent developments of physical science, the aid of Professor Joseph Henry, of the Smithsonian Institution, was obtained, and, at his suggestion, Dr. Charles M. Wetherill, an eminent chemist, was employed to conduct the investigations. The report of Professor Henry, together with that of Dr. Wetherill, containing an elaborate record of the experiments and their results, are hereto appended.

It will be proper for me to preface these documents with a brief description of the apparatus by which the buildings in question are warmed and ventilated, and at the same time to furnish some statistics illustrating its power and efficiency.

The system adopted to accomplish these objects consists in drawing a given quantity

established scientific principles for adopting the ordinarily received hypothesis of a deterioration of the air by contact with hot iron, other than the production of an extremely small quantity of carbonic acid from the floating particles of organic matter; but the burning of these would seem to render the air more pure by the destruction of any miasmatic effluvia which might be present. I was therefore led to suppose that the effects complained of might be principally due to a deficiency of moisture in the warm air; and upon subsequent investigation with the psychrometer, and the means of increasing the quantity of vapor, the truth of this hypothesis was, in my opinion, fully confirmed. Instead of producing a small quantity of vapor by exposing a surface of about three square feet of water to a temperature of from 90° to 100° in the air-chamber, as had been previously done, an abundant supply was furnished by means of an iron tube connected with the water-vessel and inserted through the side of the furnace into the midst of the burning fuel. The steam generated by this arrangement, which was suggested to me by my friend Dr. Torrey, of New York, gave sufficient vapor from the water, which it put in a state of rapid ebullition, to keep the dew-point at any required elevation. With a sufficient supply of moisture, the unpleasant sensations before mentioned were no longer experienced, the temperature was more equably distributed, and a quality of softness and salubrity imparted not before perceived. The increase of moisture prevented not only the undue evaporation of water from the lungs and all the external surface of the body, but also more readily absorbed the heat from the furnace and imparted it to the body, giving the feeling of great warmth with the same rapidity of combustion.

It is evident that the great object of warming and ventilating an apartment in the winter season is to supply it with pure air of the same degree of temperature and the same amount of moisture as that of an open space in a pleasant time in summer. To fully attain this object is a very difficult matter; but the system of warming and ventilation is certainly the best which approximates the nearest to this desirable condition. The heating of the air and preserving it at the desired temperature is the simplest part of the problem; to remove the impure air, and to supply its place with fresh air, without giving rise to unpleasant currents and unequal temperature, is more difficult; to supply the proper quantity of moisture, and to prevent its condensation, is attended with still greater difficulty, particularly when apartments containing a large number of persons are to be thoroughly ventilated. This part of the general problem is, in my opinion, an essential element of proper ventilation, although it has hitherto received comparatively but little attention in this country.

The idea is entertained by some that because the heating of a large volume of air to the required temperature of the room does not abstract the aqueous vapor which it contains, that hence evaporation from a surface of water is not required to render such air salubrious. It should, however, be recollected that when the external air is, say, at the temperature of zero, all of its aqueous vapor has been condensed, with the exception of an almost imperceptible quantity, and when this desiccated air is afterward heated to a temperature of seventy degrees its *capacity*, so to speak, for vapor, is so much increased that moisture exhales into it with great energy from all bodies from which it can be evaporated. A rapid current of ventilation of air in this condition constitutes an artificial sirocco. Dr. Wetherill's attention was, therefore, especially directed to this point, and on a first examination he reported that a constant jet of water, in the form of spray, was thrown into the chamber, which served as a reservoir into which the air was projected from the fans previous to its entrance in the halls; but this arrangement was afterward found to be merely intended to cool the air in summer, and not to supply it with moisture in the winter. For the latter purpose no arrangement was in operation, and consequently the air thrown into the chamber was in a condition of extreme dryness, and to this, and not to the impurity of the air, I would attribute, as a principal cause, the effects which have been complained of by members of both Houses of Congress.

It is conclusively shown, by the experiments of Dr. Wetherill, that the quantity of carbonic acid is not found in any part of the halls in injurious excess. It is true that in some cases, during cold weather, descending currents of air have been observed, due to the cooling of the ascending columns as they came in contact with the under surface of the roof, as was evident from the odor of gas when the burners above the ceiling were first lighted. That there is a tendency to form such descending currents is clear, since unless the air is immediately withdrawn from the space beneath the roof before it is cooled, and thus rendered heavier than the ascending air, it will descend in parallel streams; but to determine how frequent and extensive these currents are, further experiments will be necessary. The effects of them, however, were not perceptible in the analysis of the air by Dr. Wetherill.

On inquiry I found that the same deficiency exists in the necessary quantity of moisture in the air of the Treasury Department, and probably in all the other public buildings of the city. Mr. Rowland, an intelligent clerk of the Attorney General's Office, has partially supplied the deficiency in his room by means of a small gas furnace, which keeps a quantity of water in a constant state of rapid ebullition.

The admission of the proper quantity of moisture into an apartment, and also at the proper time, require careful attendance, since if the air be nearly saturated with vapor, previous to the warming of the walls to the statical degree of temperature at which they are to be retained, a precipitation will take place, and this is especially the case with the windows, although the glass be a bad conductor of heat, yet the panes are so thin that the temperature on the inside is always much lower in cold weather than that of the adjacent walls. This difficulty, however, does not exist in the halls of the Capitol, since they are not lighted by windows in contact with the external air, and it may be remedied in other buildings by double windows. It is true that the supply of the necessary amount of moisture will increase the cost of heating and ventilation, but this is a consideration which cannot, in most cases, be allowed to weigh against health and comfort.

Two methods are employed to supply air for ventilation, one of which is called that of impulsion, and the other aspiration. In the first method the air is forced into the chamber at a lower level, and allowed to escape at a higher. In the second method the air is removed from above by creating a partial vacuum, and supplied below by the pressure of the external atmosphere. I am informed that arrangements were made in the construction of the building by which both these methods could be employed at the same time, and the deficiencies of either thus obviated.

In conclusion, I may state that, as far as the inquiry has been carried, it shows that the means provided for the supply of warm and pure air to the halls of Congress are ample; that I fully agree in opinion with Dr. Wetherill that the principal cause of complaint is the deficiency in the supply of moisture; that in some cases descending currents of air may exist, but that both these causes of disquietude may be remedied without much expense or labor.

It should, however, be observed in this connection that it is impossible to supply the air of a public chamber in such a condition as to suit every individual of a large assembly of persons of different constitutions and bodily vigor. What is agreeable to one may be unpleasant to another. Besides this, however efficient may be the means of supplying air and of regulating the temperature and moisture, it is very difficult to retain it in such a condition as will be most agreeable to the larger number of the inmates of the chamber while the condition of the external air and the number of persons are continually varying.

I have the honor to remain, very truly, your obedient servant,

JOSEPH HENRY.

THOMAS U. WALTER, Esq.,
Late Architect United States Capitol Extension, &c.

REPORTS OF EXPERIMENTS UPON THE VENTILATION OF THE CAPITOL EXTENSION, BY CHARLES M. WETHERILL, PH. D., M. D.: WASHINGTON, D. C., 1865.

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Fig. 1.

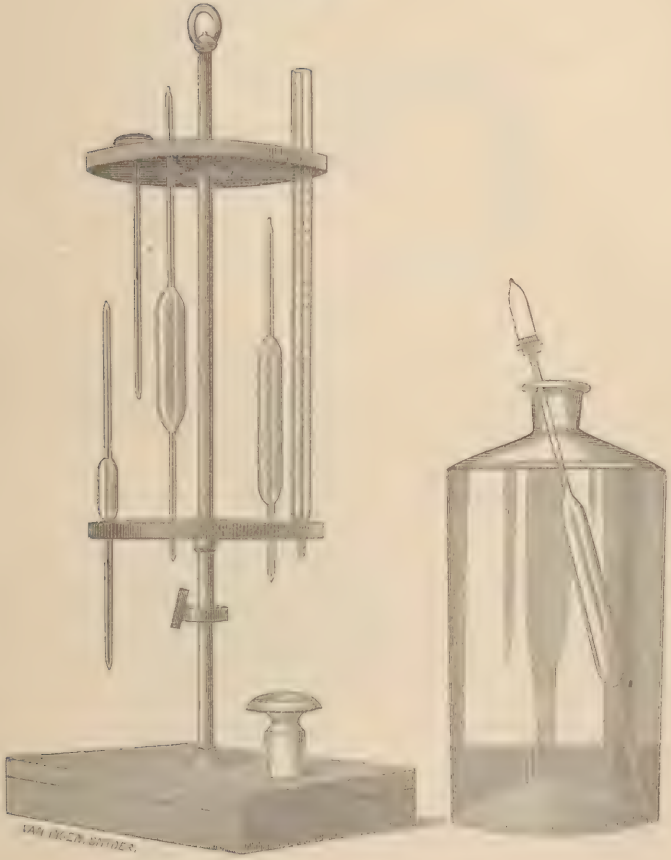
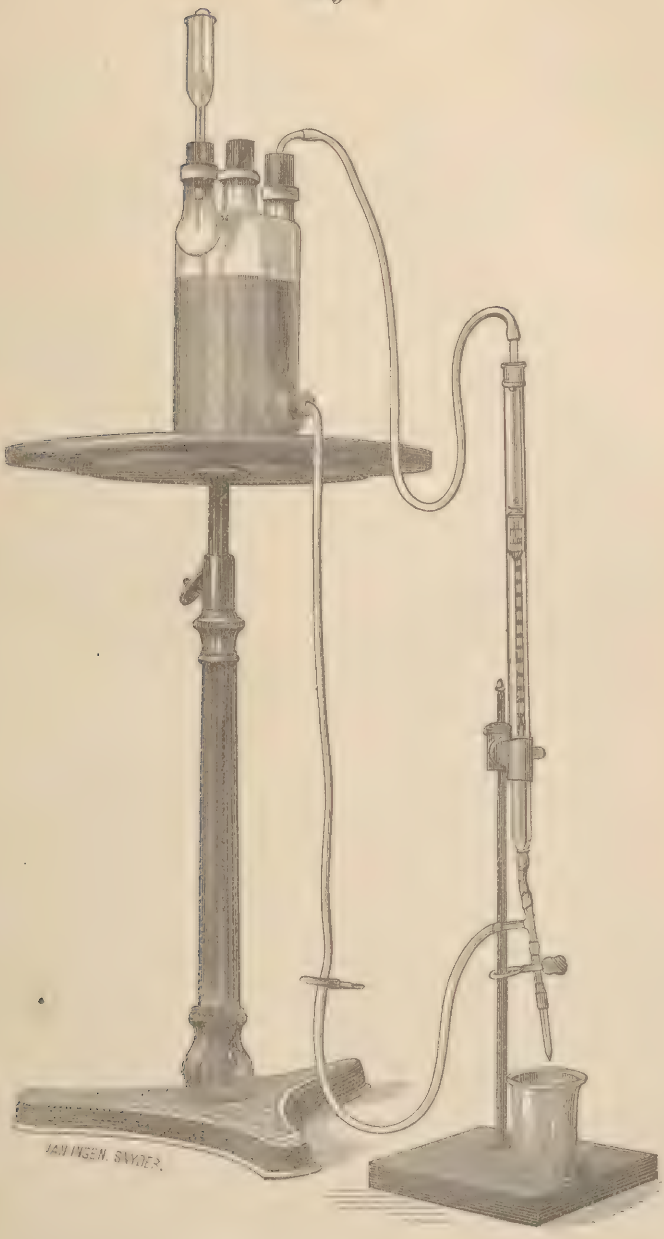


Fig. 2.

Fig. 3.



WASHINGTON, D. C., *May* 15, 1865.

GENTLEMEN: I have the honor of submitting to you the following report of my experiments upon the ventilation of the Capitol extension:

The preparation of the tests and of the apparatus, together with the numerous analyses embraced in the investigation, were effected in the laboratory of the Smithsonian Institution, and to the Secretary of the Institution I am much indebted for his coöperation, and for many valuable suggestions during the progress of the research.

In order to ascertain the actual condition of the ventilation of the Capitol extension, the importance was felt of a series of experiments, which should determine with the greatest degree of accuracy the relative amount of carbonic acid in the external atmosphere, and in the air of the halls during the session of the legislature. This is the chemical method of ascertaining the degree of ventilation, and proceeds upon the well-known principle that if the air of an inhabited room be not renewed, an accumulation of carbonic acid will take place, and hence this gas may be taken as a measure of the ventilation. We are enabled to assume this, since carbonic acid is in great excess above all the deleterious substances arising from the presence of individuals in an apartment.

The other method of determining the ventilation, which is much practiced in France, consists in measuring the velocity of the currents of air entering and leaving the apartments under consideration, from which, with other data, the actual amount of air furnished may be calculated.

Equally as important as the ventilation are the questions pertaining to the *condition* of the air furnished as to moisture, temperature, substances floating therein, and perhaps ozone. These questions you will find have received consideration in my investigations. Other subjects, such as the amount and kind of organic matter in the air, the ammonia and other gases present, &c., matters possessing a high degree of scientific interest, have been treated in my report as respects the results of others. I have neglected particular experiments of this character in order to confine the chief attention to the degree and kind of ventilation existing in the Capitol extension.

The plan selected for the determination of the amount of carbonic acid present in the air should, for the present case especially, embrace accuracy, speed, and facility of execution, capability of affording results at short intervals of time, and of performance during the actual session of the legislative bodies. It may therefore be not altogether out of place to consider here, briefly, the different methods which have been employed by chemists for this kind of analysis. These various processes may be reduced to systems, based upon one of the three following principles:

1. The measurement of the volume of the carbonic acid.
2. Its determination by the increase of weight of a substance capable of absorbing it, and through which the air is passed.
3. The transformation of the carbonic acid in the air into a chemical compound, which is subsequently analyzed, and the amount of the gas thus ascertained.

To the first mode belong Regnault's and Bunsen's methods, by which the air is dried, its volume ascertained by graduated tubes of extreme accuracy, its carbonic acid absorbed by caustic potassa, or the like, and measured by determining the volume of the remaining gases; the loss of volume being the carbonic acid. The delicate apparatus for gas analysis by Regnault, as well as that of Bunsen, were intended more particularly for the determination of oxygen, carbonic oxide, carbides of hydrogen, &c., in which a considerable difference of volume is perceptible from the reactions which take place in the course of the analysis. But carbonic acid constitutes $\frac{1}{2500}$ of the bulk of atmospheric air, of which (for fifty cubic centimeters) the diminution of volume by the removal of the carbonic acid would be only 0.02 cubic centimeter. This is a very small measure, and would give rise to errors of observation which would materially affect the determination of the carbonic acid. Regnault estimates the probable error for the determination by his method of the oxygen of atmospheric air (which contains a little over one-fifth of its bulk of this gas) at not over two hundredths of one per cent. for the oxygen: the error for carbonic acid would be much greater than this. Of the analyses quoted in this report, Leblanc has employed in part, and Lewy altogether, the process of Regnault for the determination of the carbonic acid.

According to the second principle of analysis a known volume of air is drawn, by means of an aspirator, (Brunner,) or by an exhausted globe, (Dumas and Boussingault,) through a series of tubes, of which the first contain chloride of calcium, or pieces of pumice-stone saturated with sulphuric acid, by the increase of the weight of which the water is determined. The air then passes into tubes containing lumps of caustic potassa, or the solution of this alkali contained either in a Liebig bulb or upon small fragments of pumice-stone. Mülder employs a mixture of caustic potassa and lime. The increased weight of this portion of the apparatus denotes the carbonic acid. A great many analyses have been performed by this method; but it is liable to certain errors. It is difficult to ascertain the correct weight of a large number of glass tubes, owing to the variable quantity of moisture deposited upon their surfaces from the air. It is difficult to dry the air perfectly, whether by chloride of calcium or by sulphuric acid. Klasi-

witz, (Liebig u. Kopp, Jahresbericht, ix, p. 308,) who investigated the accuracy of Brunner's apparatus, after making this same objection, found the results to be unsatisfactory and disagreeing with each other for the carbonic acid, because the sulphuric acid tubes employed for drying the air absorb carbonic acid; and in the use of chloride of calcium the tubes become light from its expulsion of chlorine by the ozone of the atmosphere. Méne, (Comptes-Rendus, xxxiii, pp. 39, 222,) who experienced difficulties in the employment of Brunner's method, determining the carbonic acid by the increased weight of a solution of caustic potassa, through which the air was drawn, assigned for cause the difficulty of drying the air perfectly before it reaches the potassa solution. He modified the process by determining the carbonic acid absorbed, by alkalimetry, thus: Having neutralized a solution of caustic potassa by an acid of known strength until it changed litmus, with which it was mixed, to a wine-red, he ascertained how much of the acid was needed to change the color to an onion-red. He thus obtained the quantity of carbonic acid originally existing in small proportion in the potassa solution. A measured quantity of the same potassa solution was then subjected to the air drawn through it by the aspirator, and after the addition of litmus, by determining the acid needed to change the color from a wine to an onion red, the necessary data were afforded for calculating the amount of carbonic acid in the air. Méne states that in his experiments for determining the relative amount of carbonic acid in the atmosphere, taken at different elevations on the Pantheon at Paris, he obtained by Brunner's method 5.1 volumes of this gas in 10,000 of air; while by his own method he found only 2.4 volumes. He then tested the solution of caustic potassa employed in the Brunner experiment by his own method, and found in it 2.5 volumes of carbonic acid, from which he inferred that the 2.6 additional volumes in the analysis by Brunner's method were due to an error which proceeded from water absorbed from the air, and which increased the weight of the potassa solution erroneously. Méne's results will be given in a subsequent part of this report. Otto (Lehrbuch der Chemie, vol. ii, part I, p. 111) criticises them as unworthy of a high degree of confidence, and the individual experiments appear, indeed, to differ too much from each other; but they are worthy of note as affording a less amount of carbonic acid than is usually accepted as existing in the atmosphere.

There is an error of small extent which attaches to Brunner's method, and which, being in the opposite direction, tends to lessen that stated above. Apparently when large quantities of air are passed over caustic potassa a certain portion escapes absorption. C. W. Elliott and F. H. Storer, (Ch. News, iii. 178,) in their experiments upon the nature of the odorous gas accompanying the evolution of hydrogen from commercial zinc, passed atmospheric air through two long tubes filled with pumice-stone imbued with caustic potassa, and then through three Liebig's bulbs filled with the same alkaline solution, and found that when one hundred and fifty-six liters of air had passed by this route into lime-water, the latter was not, indeed, at once turbid in the Liebig bulbs, but after twenty-four hours a crystalline deposit of carbonate of lime was always formed. It doubtless existed immediately in an amorphous condition, soluble in the lime-water, and afterward separated by crystallization.*

These results may throw some light upon the discrepancies of Méne, who passed ninety-five liters of air per hour through his solutions of potassa, and hence lost some carbonic acid by his method, the loss being more than compensated by the atmospheric moisture communicated to the same solution in the Brunner experiment.

3. Upon the third principle involved in determinations of the atmospheric carbonic acid—viz. the transformation of this gas into a definite compound, which is subsequently analyzed—a large number of results have been obtained. The processes of De Saussure, Thenard, Mohr, Gilm, Pettenkoffer, and others, are founded upon this principle.

De Saussure, the younger, employed large air vessels, of known capacity, which were closed by a screw pressing upon a leather washer. In these he placed, with the air to be examined, at first lime-water, and in his later experiments solution of caustic baryta, which was spread upon the sides of the vessel twenty times daily during eight days. The carbonic acid of the air formed carbonate of baryta, which was filtered off and washed, with precautions against further absorption of carbonic acid from the air; the precipitate was then dissolved in hydrochloric acid. The carbonate adhering to the sides of the air-vessel was dissolved in acid and added to the former solution, from which the baryta was precipitated and weighed as sulphate. This gave the equivalent proportion of carbonic acid by calculation, which was referred to the air-vessel and estimated by volume in 10,000 parts of air. The De Saussure experiments were among the first performed upon the carbonic acid of the atmosphere; they were very numerous, agreeing well with each other, and are quoted and referred to universally at present as authoritative upon the constitution of the atmosphere respecting this constituent. Verver, who performed ninety analyses according to Brunner's method, obtained results

* Karsten (Pogg. Ann., cxv, 343) attributes this formation of carbonic acid to the oxidation of cork, caoutchouc, and organic matter by the air. It is a pity that neither of these operators measured the quantity of carbonic acid present.

identical, in maximum, minimum, and mean, with those of De Saussure. Notwithstanding this agreement, the proportion of carbonic acid is doubtless too large. We have seen the reason for this in Brunner's method to be owing to the absorption of water from the air, or to the difference between this gain and the loss of carbonic acid which passed through the alkaline liquid; or, finally, to these plus the carbonic acid arising from the oxidation of organic matter according to Karsten's experiments. The error of De Saussure's process, if any exist, is doubtless due to the absorption of carbonic acid from the air during the subsequent operations of filtering, &c., to which the carbonate of baryta is subjected.* When we consider the greediness of the baryta solution for carbonic acid, and the extremely small amount of this acid in the air, so that a small additional and erroneous weight for the carbonate of baryta would cause a large error in the composition of the air per 10,000, it is impossible to doubt that the results obtained by this process are too high. Besides, the air is confined for a long time with the alkaline solution, and all leaks of the air-vessel, imperceptible although they be, are so long in operation that they may produce a decided effect upon the increase of carbonic acid. De Saussure's method involves also a great deal of labor in its performance. Mohr, and subsequently Gilm, under the direction of Klasiwitz, have contrived a process which is described in Mohr's Titrir-Methode, p. 445. It combines certain principles of De Saussure's and Brunner's method, and applies the process of measuring according to the system of volumetric analysis, in place of weighing. Instead of confining the air in bottles, it is drawn, by means of an aspirator, through tubes containing hygrometric substances, by which it is dried. It passes thence through a long, slightly inclined tube filled with a mixture of caustic baryta and potassa in solution, and then into a small Woulfe's bottle containing the same alkali, to all of which it yields its carbonic acid, forming carbonate of baryta. This is separated by filtration and washing, with exclusion of air, and is converted into chloride of barium, of which the chlorine is determined volumetrically by Mohr's method, with silver solution. From the chlorine the proportion of carbonic acid is obtained by calculation. It is not necessary to indicate the sources of error to which this process is liable, as they will appear from what has already been stated above. A source of error which applies to all the methods in which the carbonate of baryta is separated by filtration and its baryta determined, arises from the absorption of baryta by the filtering paper. (Dr. Eisenstück, jr., Pr. Ch., lxxxiii, p. 384.) This method, like all in which an aspirator is employed, gives only the mean amount of carbonic acid in the air during the time (several hours) that the aspirator is in action.

Pettenkoffer's process, which has been adopted in this research, appears to combine more of the advantages, and fewer of the disadvantages, of those described above. It enables air to be collected at brief intervals of time; it is of facile execution, and its results agree closely with each other.

Prior to its description by Pettenkoffer, a similar method was proposed by Watson, whose results will be quoted in a subsequent portion of this report. Méne's former process is somewhat similar. This chemist published, subsequently, an improvement, substituting baryta for potassa, in which he appears to be unaware of Pettenkoffer's method of analysis. Pettenkoffer's process consists in introducing into a bottle capable of being closed accurately, and of capacity commensurate with the amount of carbonic acid supposed to be present, 45 cubic centimeters of a solution of caustic baryta containing about 9.3 grams of the crystallized hydrate in a liter of water. These air-bottles contain about 6 liters of air for analyses of the external atmosphere, and half that volume for the ordinary air of chambers. A solution of oxalic acid is prepared of such strength that one cubic centimeter of it will saturate as much of any base as one milligram of carbonic acid. For this purpose 2.8636 grams of crystallized oxalic acid are dissolved in a liter of water, since

$$\text{eq. } (C\,O_2)22 : \text{eq. } (C_2\,O_3\,3\,H\,O)\;63 :: 1 : x = 3.8636\dagger$$

With this oxalic solution the strength of the baryta solution is determined by seeking how many cubic centimeters of the former are required to neutralize 30 cubic centimeters of the latter to the point that a drop of the mixture will not produce a brown spot or ring upon tumeric paper. The air-bottles are turned frequently so as to coat their interior surface with the baryta solution. At the expiration of two hours the baryta will have deprived the air imprisoned in the bottle of its carbonic acid, forming the insoluble carbonate of baryta, and losing, to a proportionate degree, its alkalinity. Forty-five cubic centimeters of the barytic solution have been introduced into the bottle in order to be able to withdraw 30 cubic centimeters by means of a pipette, and to allow for loss of solution adhering to the air-vessel and for rinsing the pipette. When the process of absorption is completed, the barytic solution is poured gently into a beaker glass, and after rinsing a pipette with some of it, 30 cubic centimeters are withdrawn from the bottom of the beaker. These are neutralized by the requisite cubic centimetres of the oxalic solution, and the difference between this result and the former

* Another source of error will be referred to presently.
† In Mohr's Titrir-Methode, by a typographical error, this quantity is stated at 2.409 oxalic acid.

operation upon the pure baryta is noted; to this number half of itself is added to account for the 15 cubic centimeters of the baryta solution left in the air-bottles, &c. The result is milligrams of carbonic acid, which are reduced to cubic centimeters of normal temperature and pressure, and the proportion of carbonic acid for 10,000 volumes of air is then calculated from the capacity of the air-vessel, (less 45 cubic centimeters, the volume of the barytic liquid introduced,) reduced to its normal pressure and temperature.

It will be perceived that this method resembles that of De Saussure, who employed baryta solution in air-vessels; but a much smaller amount of air is taken, which enables the analysis to be performed more rapidly. In addition to this it substitutes the delicate processes of volumetric analysis, and thus avoids the exposure of the alkaline solution to the carbonic acid of the air in filtering and washing the precipitate of carbonate of lime and the absorption of baryta by the paper. It avoids, also, the accumulation of errors of analysis incidental to the greater number of operations employed upon the said precipitate by De Saussure, Gilm, and others, to determine its equivalent in carbonic acid. It avoids the errors incident to the use of an aspirator, as in the processes of Brunner and others, and diminishes the time employed for collecting a given volume of air from several hours to as many minutes.

Pettenkoffer (Jr. Pr., ch. lxxxv, 178) has given the following comparison of his method of analysis with that of Dr. Gilm:

	By the process of— Pettenkoffer.	Gilm.
I. Carbonic acid in 10,000 volumes of atmospheric air	7.40	7.41
II. Ditto	6.11	6.33
III. Ditto	4.52	4.09

The coincidence of results in I is too close to be other than accidental, for Pettenkoffer does not claim a greater accuracy in determining the point of neutralization in adding the oxalic to the barytic solution than $\frac{1}{10}$ of a cubic centimeter, which would give a possible error of nearly 0.1 in the number which represents the proportion of carbonic acid in 10,000 volumes of air. As two acts of neutralization are performed, this error may be either doubled or reduced to zero. If Pettenkoffer's results are correct, whatever errors attach to the use of an aspirator, or to filtration, as practiced by Gilm, apply to his own method, since by a comparison they afforded the same results. I have made some slight modifications of Pettenkoffer's process, which seem to be improvements, and which, together with the reasons for their adoption, will be found in a subsequent portion of this report.

Before proceeding to any determination of the proportion of carbonic acid in the air, an examination was made of the degree of accuracy of the method selected, and of the sources and amount of errors of the processes which have been adopted.

A discussion of this subject involves a consideration of the following points, viz:

1st, the accuracy of the weights and measures; 2d, the degree of accuracy in closing the air-vessels; 3d, the purity of the tests employed; 4th, the method of arriving at the point of saturation of the alkakine solution; 5th, the influence which the probable error in observing the aforesaid point of saturation has upon the analysis.

1. The weights and measures employed in the analysis were the gram (= 15.44 grains) and the cubic centimeter, (= 0.061 cubic inch.) In passing from the weight of carbonic acid obtained by the analysis to its volume, and in calculating its proportion in 10,000 volumes of air, it is important to have a correct cubic centimeter. This is obtained by the volume occupied by the weight of a correct gram of distilled water at an observed temperature, which volume is reduced to 4° centigrade, by means of the coefficient of expansion of water. The weights and graduated vessels obtained from the best instrument-makers are frequently incorrect, and hence a particular examination of such as were used in these experiments became necessary. The result demonstrated the existence of inaccuracies, which were corrected. A portion of this work was performed in the Bureau of Weights and Measures, and I am much indebted to Joseph Saxton, esq., for his valuable coöperation in graduating the air-vessels with the delicate standard balances of this Bureau. The Bureau of Weights and Measures is the depository of a complete set of standard weights and measures which were presented by the government of France to the United States. These have been compared with the platinum kilogram in the archives of the department of state of France, by M. Silberman, superintendent of the Conservatory of Arts and Trades, whose report upon the subject is contained in the report to the Senate of Professor Bache, Superintendent of Weights and Measures, (Ex. Doc. No. 27, 34th Congress, 3d session, p. 138.) The weights used for the analysis were box No. 798, of Oertling's manufacture. The small weights of the subdivisions of 50 grams were found to be exactly equal to the 50-gram weight, which is itself equal to 50.0009 grams, according to the standard in the archives of the French state department. The air-vessels were graduated by Mr. Saxton and myself, employing distilled water and the large French weights of page 160 of Professor Bache's report. Their volume was calculated for 4° centigrade, and account was taken of the air escaping from the bottles before the second weighing.

All of the other measures—the burettes, pipettes, &c.—were graduated by box No. 798 of Oertling's weights; and the temperature of the water was taken at 17½° centigrade for the standard, according to Mohr's practice in volumetric analysis. Since 45 cubic centimeters of solution of baryta are poured into the air-vessels, this volume must be deducted from the capacities of these vessels, respectively, to ascertain the amount of air taken for the analysis. But a liter, according to Mohr's graduation, measures really 1,001.2 cubic centimeters; hence, 45 cubic centimeters, according to his measurement, would equal 45.05 cubic centimeters, and hence I have deducted 45.01 cubic centimeters from the air-vessels to obtain the quantity of air taken for the analysis. The following table contains this quantity for the bottles, together with their logarithms employed in the calculations:

Table of quantity of air taken for analysis.

Designation of bottle.	Cubic centimetres, less 45.1.	Logarithms C. C. of air.
A	7916.6	3.89854
B	7470.1	3.87333
C	7652.5	3.88380
a	3556.7	3.55105
b	3005.2	3.47787
c	3031.2	3.48161
d	3255.8	3.51266
e	3315.7	3.52058
f	3171.1	3.50121
g	3064.7	3.48639

The full pipettes (Fig. 1) employed in the analysis were graduated by the weight of distilled water at 17°.5 centigrade, which dropped from them; and the error of the burettes was determined by weighing the successive volumes of ten cubic centimeters (read by means of Erdmann's swimmer) which they discharged. The liter measures were also tested and corrected.

2. The vessels (Figs. 1 and 3) for confining the air in contact with the solution of baryta, were closed with accurately-ground glass stoppers. It was deemed important to determine the degree of tightness of these stoppers, so that the air might remain sufficiently long exposed to the action of the baryta without danger of the absorption of carbonic acid from the external air by diffusion. To effect this purpose the stoppers were reground carefully with flour of emery, coated with a film of glycerine and inserted in the bottles, which were then inverted in a vessel of water and placed in a vacuum; by which experiment it was ascertained that the stoppers were perfectly air-tight. This fact was also proved by the following experiment: Three specimens of the same external air were taken and solution of baryta added; of these, B and C were analyzed at the expiration of 3 hours, and A at the expiration of 22 hours, with the following results:

B contained .... 2.685 volumes of carbonic acid,
C contained .... 2.719 volumes of carbonic acid,
A contained .... 2.722 volumes of carbonic acid,

in 10,000 volumes of air. Hence the absorption of carbonic acid was complete at the expiration of three hours, and the delay of a day in performing the analysis did not involve any error arising from the diffusion of carbonic acid external to the apparatus. In consequence of this result, and to insure perfect absorption of the carbonic acid, the specimens of air were always analyzed on the day after they had been collected. The analysis of duplicate or triplicate specimens of external air always agreed closely, and when the bottles containing them were opened in the warm laboratory the expanded air always rushed out with a noise.

In the method described by Pettenkoffer, the baryta solution remaining in the air vessels after the action thereupon of carbonic acid, *is poured out* into a small beaker glass, and after the 30 cubic centimeter pipette has been washed out with a small portion of this solution, it is filled with sufficient of the remainder for the determination of its alkalinity. It would seem that, by such a procedure, there is danger of an increase of carbonic acid by exposure to the air. When the pipette is not protected, the inside of the stem becomes quickly coated with carbonate of baryta, and the act of pouring the baryta must necessarily subject the same to carbonic acid. I sought, therefore, to improve the process by employing a 30 c. c. pipette of sufficient length to reach to the bottom of the liquid in the carefully-opened air bottle (as shown in Fig. 1) from which, after rinsing the pipette, the baryta solution is immediately drawn. In

Pettenkoffer's early experiments the baryta solution was neutralized in the air vessel. The upper stem of the pipette I protected from carbonic acid in the air by a small tube containing a mixture of caustic lime and Glauber's salt. A similar protection extends to the air entering the bottle containing the supply of baryta solution needed for adding to the air vessels. The 45 c. c. pipette is filled from this bottle by means of a glass tube reaching to its bottom and furnished at the top of the tube with a piece of gum-tubing, closed with Mohr's spring clamp. (Fig. 2 illustrates this method of confining and pipetting the baryta solution.) Experiment demonstrated, by daily determinations of its title, that baryta test solution thus preserved maintained its strength unimpaired.

In collecting air for analysis the stoppers were always inserted carefully to avoid compressing the air. The air was introduced into the air vessels by the action of a bellows with an India-rubber tube reaching to the bottom of the bottle, as illustrated by Fig. 3.

3. It is plain that, other things being equal, the accuracy of the results depends upon the purity of the oxalic acid employed. In the described method, this acid, purified by crystallization from oxalate of potassa, is dried in vacuo over sulphuric acid, at the ordinary temperature. If these crystals contain mother-water in their pores or cavities they will have the composition $C_2O_3 3HO + xHO$, and will give the result of too much carbonic acid in the air; if the exposure in vacuo at the ordinary temperature of the laboratory is prolonged there is danger of their losing some of the water of crystallization, and thereby yielding too little carbonic acid. The experience of this research has demonstrated the necessity of ascertaining the strength or title of the oxalic acid by a special volumetric analysis, by means of pure carbonate of soda. In this process the oxalic solution was prepared with 2.8636 grammes to a liter of water, as if the acid were pure, and then, by a neutralization with pure carbonate of soda, a factor was obtained by which to multiply the measures of oxalic solution to correct the errors arising from the impurity of the acid. A small quantity of oxalic acid, prepared for the experiments of the summer of 1863, was thus found to be impure from excess of water. A pound of the acid, purchased from Luhme & Co., supposed to be chemically pure, was found to contain binoxalate of potassa, from which it could not be freed by less than four crystallizations, according to Mohr's process. An exposure to sulphuric acid in vacuo was prolonged until it was feared that the crystals had effloresced. The microscope, however, demonstrated that such was not the case; but, upon determining the title by carbonate of soda, the presence of a larger quantity of water than the formula $C_2H_3 3HO$ warranted was ascertained. It resulted from the experiments that this oxalic acid always gave a solution of the same strength, although below the normal one. Its volumetric analysis by the carbonate of soda was effected in the following manner:

A quantity of bicarbonate of soda, purchased for chemically pure, but which contained, by analysis, iron, chloride, and sulphate, was purified and converted into neutral carbonate in the usual manner. Analysis then demonstrated that 2.812 grammes of the salt contained 2.807 pure carbonate and 0.005 sulphate of soda. A solution of this salt was made of such strength that a cubic centimeter would exactly neutralize the same measure of Pettenkoffer's oxalic solution made with pure acid. This requires the oxalic acid and carbonate of soda to be present in the proportion of their equivalents, viz:

63 (eq. oxalic acid) : 53.18 (eq. carb. soda) : : 2.8636 : $x = 2.4172$; but since 2.807 of pure carbonate of soda is contained in 2.812 of the carbonate of soda employed, instead of 2.4172 we must take 2.4215 of this salt, and dissolving it in a liter, we will have a solution which would exactly neutralize a liter of normal oxalic acid solution.

A little more than this quantity of carbonate of soda was ignited in a platinum crucible, and weighed after cooling over sulphuric acid; it was then brought to the exact weight required, then heated again and weighed repeatedly until it was certain that no hygrometric water impaired the correct weight. The salt was then dissolved in an accurate liter of distilled water of 17°.5 centigrade.

Thirty c. c. of this solution were measured at 17°.5 C. into a beaker glass, to which ten drops of the litmus solution, employed in these experiments, were added. This litmus solution was neutralized by nitric acid until it was of wine-red color; forty drops required 0.495 c. c. of the oxalic acid solution to produce an onion-red tinge; consequently ten drops of the litmus would require 0.124 of the acid for the production of this shade of color. By the mean of four experiments it was ascertained that 30 c. c. of the above-mentioned carb. soda solution required 31.323 c. c. of oxalic solution in the corrected burette to produce an onion-red color after boiling. This volume corrected for the alkalinity of the ten drops of litmus is equal to 31.199 c. c., and x $(31.199) = 30$ or $x = \frac{30}{31.199} = 0.96157$, of which the logarithm equals 1.9829806. This experiment was repeated with the same result upon another preparation of oxalic acid solution, and consequently the volumes of this acid obtained in the course of the analyses, from which the amount of carbonic acid was determined, were always corrected by multiplication by the number 0.96157.

4. For determining the point of neutralization by adding the oxalic to the baryta

solution, Pettenkoffer adopted the reaction upon turmeric paper. He states that in employing litmus solution for this purpose he found an uncertainty in determining the point of neutralization, extending from 1½ to 5 cubic centimeters of the oxalic acid solution. In consequence of this he let fall a drop of the solution, at intervals during the progress of saturation, upon a piece of turmeric paper, and arrested the process when a brown ring was no longer visible. As the employment of litmus would facilitate the research, experiments were instituted to ascertain whether it could be used. They resulted satisfactorily, and the following is the improved method adopted. To the baryta solution ten drops of a strong and nearly neutral solution of litmus were added. It is not necessary to take into account either the alkalinity of this litmus or the slight error of the burette, since the carbonic acid is determined by the difference of two reactions which are precisely alike, with the exception of the presence of a precipitate of carbonate of baryta in the second reaction. These two cases neutralize also the error which might arise from an absorption of carbonic acid from the air in pipetting the baryta solution." The oxalic solution is added until a point is reached when the blue color of the liquid changes suddenly to violet. The beaker containing the solution is then slightly warmed, which expels carbonic acid, and causes the complete subsidence of the precipitate of oxalate of baryta. A microscopic examination demonstrated that this precipitate is as soon as formed, and without the application of heat, crystalline. It now requires a small amount of the oxalic solution to bring the liquid to the desired shade of red at which the operation is arrested. This shade is incipient onion-red. To produce it drop after drop of the oxalic acid is suffered to fall into the almost clear liquid, until the falling drop is no longer visible. The precipitated mixture of carbonate and oxalate of baryta is tinged *blue* by the absorption of the coloring matter of the litmus when the point of neutralization has been reached. If after the neutralization is complete the drops of oxalic acid reach this blue precipitate while suspended in the liquid, the color will be changed to red; but if they fall into the clear liquid, and become thus diluted before mingling with the precipitate at the bottom of the beaker, they will produce no effect upon its color. If the glass containing the liquid be suffered to stand for some time after the completion of the experiment, the precipitate is changed slowly from a blue to a red color. Perhaps it would be of advantage to arrest the operation of adding the oxalic solution at the appearance of the violet color; but the point of the onion-red having been adopted at first, was maintained for all of the experiments. This point has the advantage that the operator is prepared by the advent of the violet tinge to add the oxalic test with caution. None of the experiments were lost by excessive addition of the test acid. There is nothing to prevent the use of turmeric paper, together with the litmus, in its two stages of violet and red tinge, taking the mean result of the three indications; or, if losing the point of neutralization by the turmeric paper, saving the analysis by means of the litmus reaction. In the series of experiments performed in June, 1864, turmeric paper was employed, and the experience derived from the present series has demonstrated the equal delicacy as well as the superior convenience of the litmus solution in analyses of this character. The following experiments, showing the number of cubic centimeters of oxalic solution required to neutralize thirty c. c. of the solution of baryta, arresting the operation at the points indicated above, prove the accuracy of the method adopted:

Number of experiment.	Turmeric brown.	Violet tinge.	Onion-red.
1	Lost.	37.0	37.2
2	36.2	37.0	37.2
3	36.0	36.9	37.2*
4	36.2	36.9	37.2

The differences between the turmeric brown and violet tinge are, respectively, 0.8, 0.9, and 0.7. Between the onion-red and violet the differences are 0.2, 0.2, 0.3, 0.3; between the turmeric brown and onion-red they are 1.0, 1.2, and 1.0.

I observed that the point of neutralization could be determined more closely with the baryta solution before than after its exposure to the carbonic acid of the air in the vessels. I have been unable to ascertain, with any degree of certainty, the cause of this, which might arise from a solvent action of the acid upon the carbonate of baryta; but in order to diminish possible errors from this source, I have always arrested the neutralization in the second case very closely to the onion-red tinge, although not quite at this point. If there be any error in such a procedure it would tend to yield a trace more of carbonic acid than is really present.†

* Since the hydrate of baryta employed in preparing the test solution contained carbonate, the filtered test solution is saturated with the said carbonate. *Vide* De Saussure's experiments.

† This would not affect the object of the present report, since the determination of carbonic acid in apartments was always relative to a simultaneous analysis of the external atmosphere.

5. From the foregoing considerations it is apparent that the degree of accuracy of the method depends upon the correctness with which the *point of neutralization* is observed. Experience in graduating the full pipettes employed in measuring the baryta solution proves that they always indicate very nearly the same amount of liquid. The burette furnished with Erdmann's swimmer, and graduated to 0.2 cubic centimeter, may be read very accurately to 0.1 cubic centimeter, or even less. Suppose that a mistake of $\frac{1}{10}$ cubic centimeter be made in determining the point of saturation of the baryta solution. Since considerable uniformity exists in the capacities of the air vessels as well as in the amounts of carbonic acid resulting from the analyses, we may calculate the probable errors of the analyses as follows: In experiment No. 3, of February 8, 1865, by which 2.719 carbonic acid was found in 10.000 volumes of air, an error of —0.1 cubic centimeter of oxalic solution in the neutralization would give 2.622 carbonic acid, or an error of —0.097. One-tenth of one part in ten thousand, or one one-hundred-thousandth, would therefore be the probable error in the determination of the carbonic acid when operating carefully. In nearly every instance duplicate analyses of the air were performed, and the average of the results was taken. It has been deemed expedient to present in this report all of the data afforded by the experiments, together with the method of calculating them, so that, in the event of future improvement of this method of analysis, a recalculation of the results (if needed) may be effected. The calculations were performed by logarithms, and, to avoid errors, were repeated twice, and in some instances three times. In reducing the volume of the air taken for each analysis to 0° centigrade and 760 milimeters barometric pressure in the usual manner, the logarithms for $(1 + \delta\, t)$ and $\frac{B}{760}$, in which B = the barometric pressure reduced to 0° C., t the temperature of the air in air-vessels, and $\delta = 0.003665$, were taken from Marchand's tables. These logarithms were added when B was below 760^{mm}., but when B was above 760 its logarithm was subtracted from the logarithm $1 + \delta\, t$, and the sum or difference thus obtained was subtracted from the logarithm of the air-vessel (see page 14 of this report) to reduce the quantity of air taken to its normal temperature and pressure. The milligrammes of carbonic acid afforded by the analyses were corrected for the abnormal condition of the oxalic acid test by adding to their logarithms $\overline{1}.9829806$. which is the logarithm of the factor 0.96157. The further addition of the logarithm $\overline{1}.7015680$ translated the weights into cubic centimeters of carbonic acid (sp. gr. carbonic acid = 1.5291) of normal pressure and temperature; and the addition of 4 to the characteristic of this logarithm gave the calculation for 10,000 volumes of air. These operations were abridged by adding the constant logarithm 3.6845486 to the logarithm of milligrammes of carbonic acid proceeding from the experiment, and subtracting therefrom the logarithm of the air taken at normal temperature and pressure. The number corresponding to this logarithm gives the volume of carbonic acid in 10,000 measures of air.

The following example of the calculation of analysis No. 46 will sufficiently illustrate the method of computation:

In this experiment the air-vessel A (log. 3.89854) was filled with air of temp. 4° C., at a barometric pressure reduced to 0° C. of 759^{mm}. Forty-five cub. cent. of baryta solution, of such strength that 30 c. c. required 37.5 c. c. of oxalic acid for neutralization, were introduced into the air-vessel, and the stopper, coated with glycerine, was inserted. On the following day 30 c. c. of the baryta solution were removed from the air-vessel; they required 34.6 c. c. of oxalic solution for neutralization; then—

Log. $(1+\delta 4°)$ =	0.00632	Log. A =	3.89854
Add log. $\frac{759}{760}$	0.00057		0.00689
	0.00689		3.89165 log normal vol. air.

Cub. cent.

37.5 title of 30 cub. cent. baryta solution before exposure to carbonic acid.
34.6 title of 30 cub. cent. baryta solution after absorption of carbonic acid.

2.9
+ ½ 1.45 to account for the 15 c. c. baryta solution left in the air-vessel.

4.35 log = 0.6384893
Add 3.6845486

4.3230379
Subtract 3.89165

0.43139 = 2.7 carb. ac. in 10,000 vols. air.

Fig. 4 represents the method of neutralizing the solution of baryta before and after it has been acted upon by the carbonic acid of the air confined in the air vessels. The three-necked bottle contains the normal solution of oxalic acid, which, by pressing the spring clamp attached to the caoutchouc hose connected with the bottle, rises in the Mohr's burette, where it is measured very accurately by means of the Erdmann swimmer. Upon pressing the clamp at the extremity of the burette, the test acid is dropped and measured into the beaker glass containing the baryta solution tinged with litmus. While filling the burette its air passes into the three-necked bottle by means of the hose connected with the top of the burette, and in measuring off the acid, air enters the Woulfe bottle by a water-valve sealed by some of the oxalic solution. By this arrangement a very rapid and accurate neutralization is effected.

EXPERIMENTS UPON THE MOISTURE IN THE AIR.

Cotemporaneously with the carbonic acid determinations, and in some instances without them, the amount of moisture present in the air was ascertained by the difference in temperature of correct dry and wet bulb thermometers. This method by psychrometry was preferred to the more accurate one of Regnault for determining the dew-point, as being sufficiently accurate for the purpose while it enabled a comparison to be made with the results of the meteorological observations of the Smithsonian Institution and of others throughout the country, and at the same time was of very ready execution. The thermometers were all carefully compared before employing them in the experiments. Three pairs were used in the course of the investigation. In experiments 1 to 34 I employed a pair of fine centigrade thermometers belonging to the Smithsonian Institution, and capable of estimating quarters of a degree.

In experiments 34 to 83 I used a pair of centigrade thermometers of German construction, graduated to fifths of a degree, and estimating tenths with perfect accuracy. The instruments placed side by side in iced water stood at 0°, and were found to be equivalent, degree by degree, beyond the highest temperature observed during the research. Placed side by side in the air, and observed for different temperatures during several days, they stood always alike.

Unfortunately one of these thermometers was broken, and reliance was had for the remainder of the observations upon a Mason's hygrometer containing Fahrenheit thermometers. This instrument was compared with the unbroken thermometer used in experiments 34 to 83, and was found to agree with it. It had the disadvantage of rendering fifths of a degree by estimation with difficulty. The results by this hygrometer were translated into centigrade degrees, and all of the calculations for humidity were performed by the use of Guyot's tables. (Smithsonian Misc. Coll.)

A table comprehending the data and results of the determinations of carbonic acid and humidity will be found upon a subsequent page of this report, which position was assigned to it so that we might first consider the observations of other chemists and physicists upon ventilation, after which a comparison and discussion of the results obtained by the present research would follow most naturally.

I. CONSTITUTION OF THE ATMOSPHERE.

I. INTRODUCTION.

In consulting the numerous works upon ventilation placed at my disposal by the Smithsonian Institution, I have been surprised at the sameness of many of them, each author copying much of the matter of his predecessors and adding little new. I have thought, therefore, that it would be interesting to refer to the original investigations and analyses of those who have determined the constituents of the atmosphere, or, where that was impossible, to other publications containing full accounts of such experiments. This an extensive search in the library of the Smithsonian Institution and in my own library has enabled me to do; but a difficulty presents itself in condensing the numerous references within the narrow limits of a report.

The atmosphere plays the main part in ventilation; hence the importance of ascertaining the nature and proportion of its constituents in both normal and abnormal conditions.

What Humboldt says of climate applies to the interior of an apartment occupied by an assemblage of individuals. (Humboldt Fragmens de Climatologie et de Géologie Asiatiques, Paris, 1831:) "The word climate, in its most general acceptation, embraces all the modifications of the atmosphere by which our organs are affected in a sensible manner; such as temperature, humidity, the variations of barometric pressure, the tranquillity of the air, or the effects of the different winds, the electrical charge or tension, the purity of the atmosphere or its admixture with gaseous emanations more or less insalubrious; finally, the degree of habitual clearness, that serenity of sky so im-

portant through the influence which it exerts not only by the irradiation of the soil upon the development of the organic vegetable tissue, and the ripening of fruits, but also by the moral effects which man experiences in the diverse zones."

Notwithstanding the rapid progress of science, we are far from being able to assign its due effect upon the human system of any of the above-mentionted conditions, and we can certainly not produce in the air of an inclosed, occupied space the salubrious conditions of the external atmosphere. It is the object of a well-ordered ventilation to advance in this direction as far as possible with our present limited knowledge.

It was only towards the close of the last century that the nature of the principal atmospheric constituents began to be understood. In 1774 Priestly and Scheele discovered oxygen in the air, and described the properties of this gas, at the same time discovering another constituent of the air, to which, later, the name nitrogen was given. In the same year Bergman detected carbonic acid in the atmosphere, a gas already known to Von Helmont, but which Lavoisier, in 1776, ascertained to be a combination of carbon with oxygen. Scheele observed also the presence of ammonia in the air.

The true nature of water, one of the most important of the aerial constituents, was unknown until Lavoisier determined it in 1783. At that time it was generally believed that water was an elementary body and could be converted into atmospheric air, and conversely, until De Luc (Idées sur la Météorologie) refuted the error by an extended argument. (Meteorologie von E. E. Schmid, p. 14, Karsten Allgemeine Encyklopaedie der Physick.) The accurate nature and the quantity present of these constituents was not determined until the present century, and their study is still prosecuted; while ozone and the presence of organic germs and other solid matters, with effluvia, and the nature and effects of respiration, are discoveries of our own day.

The following chronological review of the experiments upon the atmospheric oxygen and carbonic acid, quoted from Schmid, in Karsten's Encyklopaedie der Physick, are interesting, showing the progress of the science:

Chronological view of eudiometric experiments.

1774.—Scheele: "The air must consist of two kinds of electric fluids."—Chemical Treatise on Air and Fire, Leipzig, 1777, § 8–23. "Atmospheric air contains, as it appears, a fourth part of purest or dephlogisticated air, about $\frac{3}{4}$ or $\frac{11}{16}$ of phlogisticated air, and about $\frac{1}{16}$ of fixed air."—Id. 5, 216.

1775.—Fontana: Discritzioni ed usi di alcuni stromenti per misurare la salubrita dell'aria—Firenze, 1775.

Landriani: Ricerche fisiche intorno alla salubrita dell'aria, 1775.

The inferences from these researches owing to the errors of the nitric oxide eudiometer, were that the amount of oxygen in the air was variable, and was the cause of its healthfulness, on the contrary. Compare Kopp Geschichte der Chemie Bd. 3, S. 209, Braunschweig, 1845.

1778.—H. B. De Saussure performs eudiometric experiments in the southwestern Alps. He employed the nitric oxide eudiometer, and arrived at the incorrect result that the proportion of oxygen is less on the heights than in the valleys.—Voyages dans les Alps, Neufchatel, 1787–1796, § 578, 1,113, &c.

1790.—De Marty is led, by experiments in Catalonia with sulphide of calcium, to assert that the proportion of oxygen in the atmosphere is constant.—Gilb. Ann. 19, 389.

1799.—Berthollet recommends the phosphorus eudiometer, and makes observations with it at Cairo.—Memoires sur l'Egypte publees pendant les campagnes du Général Bonaparte. Paris, An. 8, pp. 284—294. In Gilb. Ann. 5, 341.

1800.—Davy's experiments in England confirm the results of De Marty.—Jour. Royal Inst., 1801, p. 45.

1802.—Berger: Experiments in the Savoyard Alps and in the Jura. Comparison of the results of the phosphorus sulphide of potassium and nitric oxide eudiometer.—Journal de Physique, I, 54, p. 366, and Gilb. Ann. 19, 412.

1804.—Dalton finds the air on the peak of Helvelyn, in Cumberland, at an elevation of 1,100 yards, and that in Manchester of the same composition.—Gilb. Ann. 27, 387.

1805.—Gay Lussac, and Von Humboldt: Examination of eudiometric methods. Recommendation of Volta's eudiometer. Experiments in Paris upon the atmosphere at different seasons and in different weather.—Jour. de Phys. I, 60, p. 129. In Ann. 20, 38. "Atmospheric air contains 21 p. c. oxygen gas, by volume, without variation."—Gilb. Ann. 20, 92.

1809.—Configliachi: Experiments upon the southern Alps and Appenines, upon wet meadows and in rice fields, and in apartments filled with persons, yield almost exactly the same proportion of oxygen.—Sull' análisi dell' aria contenuta nella vesica natatori dei pesci. Pavia, 1809; also Schweigger, Neues Jour. für Ch. und Phys. Nurnberg, I, 144.

1832.—Brunner: Perfection of the method of determining both constituents of the atmosphere.—Pogg. Ann. 27, 1.

1834.—Brunner: Experiments upon the Faulhorn.—Pogg. Ann. 31, 1.

1840.—Boussingault: Experiments in South America.—Ann. de Ch. et de Phys. Ser. 2 76, 360.

1841.—Boussingault and Dumas: Perfection of the improved methods by their performance upon a large scale.—Ann. de Ch. et de Phys. Ser. 3; 3,257. Abstract in Pogg. Ann. 53, 391.

Bouissingault and Dumas, Brunner, Martins and Bravais: Cotemporaneous observations at Paris, (Jardin des Plantes,) Bern, and at the hospice upon the Faulhorn.—Ann. de Ch. et de Phys. Ser. 3; 3, 301.

1842.—Marignac: Experiments at Geneva.—Comptes. Rend., xiv, 379.

Stas: Experiments at Brussels.—C. R. xiv, 570.

1843.—Lewy: Experiments on the North Sea and in the Danish islands.—Ann. de Ch. et de Phys. Ser. 3; 8, 425.

1849.—Regnault and Reiset: Accurate experiments by the aid of the Volta eudiometer.—Ditto, vol. 26, p. 341.

1852.—Lewy: Experiments upon the Atlantic Ocean and in South America.—Ditto, vol. 34, p. 1.

Chronological view of carbonic acid experiments.

1774.—Bergman: Discovery of carbonic acid in the atmosphere.—See Kopp, Geschichte der Ch. 3, 283.

1787.—H. B. De Saussure: Its detection in the air of the Col du Géant and of Mont Blanc.—Voyage dans les Alps, § 2,010, 2,077.

1791.—Von Humboldt: Experiments upon the atmosphere.—Brunswick, also, reports in Gilb. Ann. 3, pp. 77–90.

1801.—Fourcroy: Système des connaissances chimiques.—Paris, vol. 1, p. 158. Approximate results.

1813–'18.—Thenard: Traité de chimie élémentaire theorique et practique.—Paris, vol. I, p. ed. 5, p. 303. Quantitative method of determining carbonic acid.

1816.—Th. De Saussure: Bibliothèque universelle, T. 1. In Gilb. Ann., 54, 217. Comparison between summer and winter.

1820.—A. Vogel on the small quantity of carbonic acid contained in the air over the surface of the Baltic. Gilb. Ann. 66, 93.

1822.—A. Vogel, Gilb. Ann. 72, 277. The same in the atmosphere over the surface of the channel.

1828.—Th. De Saussure: Ann. de Ch. et de Phys., 38, 411, and Pogg. Ann., 14, 390.

1830.—Th. De Saussure: Id. 44, 5, and Pogg. Ann. 19, 391.

1832.—Brunner: Pogg. Ann., 24, 305, new anthrakometer.

1834.—Watson: Rep. 4th meeting of the British Association, p. 583.

1835.—Bousingault: Recherches sur la composition de l'atmosphère, 2me Memoire, Compt. Rendus, T. 1, p. 36.

1843.—Lewy: Recherches sur la composition de l'atmosphère, mémoire lu à l'Académie des Sciences, le 7 Âout, 1843.

1843.—Boussingault: Recherches sur la quantité de l'acide carbonique contenue dans l'air de la ville de Paris: Ann. de Ch. et de Physique. Sér. 3; 10, 456.

1844.—Boussingault et Lewy: Observations simultanées faites à Paris et à Andilly, près Montmorency, pour rechercher la proportion d'acide carbonique contenue dans l'air atmosphérique. Ann. de Chim. et de Phys. Ser. 3; 10, 470.

1849.—H. & A. Schlagintweit: Investigation upon the carbonic acid in the atmosphere of the eastern Alps. Pogg. Ann., 76, 442.

1852.—A. Schlagintweit: Upon the quantity of carbonic acid in the upper regions of the atmosphere. Experiments in the western Alps. Pogg. Ann., 87, 293.

1852.—Lewy: Recherches sur la constitution de l'atmosphère. Ann. de Ch. et de Phys. Ser. 3; 34, 1.

An examination of this chronological view demonstrates that it is only in modern times that we begin to have a correct knowledge of the principal constituents of the atmosphere. The most important of the results of the above authors will be given in the pages of this report, and the literature of the subject will be extended to the present time, in which the chemical investigation of the atmosphere is confined to its ozone, minute solid bodies, and misмata contained therein, ammonia, &c.

Constitution of the atmosphere; its carbonic acid, oxygen, and nitrogen.

The atmosphere, when deprived of its carbonic acid and aqueous vapor, contains:

	By weight, per cent.	By volume, per cent.
Oxygen	23	21.00
Nitrogen	77	99.00
	100	100.00

In its natural condition, 10,000 volumes of air contain about 4 of carbonic acid; and 100 volumes contain an average of 0.84 watery vapor.

The proportion of oxygen in dried air does not vary sensibly, but in the natural state there is a considerable variation, due to the ever-changing quantity of water which it contains; thus with 0.84 volumes per cent. of water, the atmosphere contains 20.82 volumes per cent. instead of 21 of oxygen. In Benares, on the Ganges, where the absolute amount of moisture rises to 3.6 per cent., the oxygen volume per cent. of such an atmosphere is equal to 20.24. (Graham Otto, Lehrbuch, ch. II, part 1, p. 138.)

The carbonic acid, small in quantity though it be, is sufficient, and is as essential to vegetable life as oxygen is necessary to animal life. Animals inhale oxygen and exhale carbonic acid, while plants absorb carbonic acid, appropriate its carbon for their tissue, and reject the oxygen. A balance is thus maintained in the atmosphere like that which we are able to effect upon a small scale in an aquarium. While this small amount of carbonic acid is ample for all the vegetation upon the globe, the oxygen is in great abundance for the purposes of animal life.

Poggendorf (Handwörterbuch der Chemie, Atmosphere) has given the following curious calculation of the actual amount of oxygen present in the atmosphere, and what portion of it is needed for the respiration of the human race. He estimates the height of the atmosphere at only one geographical mile (24.555 Paris feet) of air, supposed to be of the same density throughout as that of the atmosphere at the level of the ocean, and the total volume of air to be equivalent to a cube of 210 miles side; hence the cube representing the volume of oxygen will have a side equal to 125 miles, = 1,954,570 cubic miles. An adult man consumes 25.04 Paris cubic feet of oxygen in 24 hours; in a year, therefore, 95.052 cubic feet; and the total human race, estimated at one thousand millions, would require for a year's respiration 9,505,200,000,000 cubic feet of oxygen, which equals 0.7975, or nearly $\frac{8}{10}$ of a cubic mile. If one thousand millions of persons had lived always upon the earth, and were able to consume the last atom of oxygen, the quantity present would last them 2,451,000 years; or, from Adam's time to the present they would have consumed only $\frac{1}{408}$ of the oxygen. A single tenth of a per cent. of the atmosphere would provide the whole human race with oxygen for ten thousand years. From this calculation the inference is drawn that immense quantities of oxygen might be added to or withdrawn from the atmosphere without being perceived by our most delicate methods of analysis. Estimating a loss of oxygen from the respiration of animals, combustion, and other sources of oxydation, equal to a hundred fold that caused by mankind, it would require these united causes to act for one thousand years to cause the disappearance of one per cent. of oxygen from the atmosphere. Similar calculations by Marchand and by Wackenroder establish the enormous quantity of oxygen in the air compared with that which is needed for the support of animal life. The plants restore whatever loss may arise from the above causes; but whether the compensation is absolutely exact, or whether the oxygen is steadily increasing, or in like manner diminishing, it is impossible to determine by analysis, owing to the imperfections of our instruments and processes, and the brief periods which the researches embrace.

An *exact* compensation is improbable; if there were such, there could be no carbonic acid in the atmosphere. If, again, the plants reduced as much carbonic acid as the *animals* exhale, they would increase in proportion to the quantity of this gas proceeding from combustion, volcanoes, gas-springs, &c. But it is well known that plants are constantly forming humus, and that large deposits of coal are buried in the earth. As this involves a disappearance of carbonic acid, the atmosphere was formerly richer in this gas than now. Hence the effect of plants, united with that of the moist earth and of the ocean, overcomes the effects which carbonic acid produces; the atmosphere becomes continually poorer in carbonic acid, and plants would ultimately be restricted in their growth without some other source of the gas unknown to us. To establish these conclusions it would require the most accurate determinations of the atmospheric oxygen and carbonic acid, to be performed during the period or at the intervals of a century. (Poggendorf.)

The question whether the *oxygen* in the atmosphere experiences a diminution by the respiration of men and animals, stands in intimate connection with the inquiry whether the proportion of atmospheric *carbonic acid* increases from these processes. By the oxidation of carbon to carbonic acid one volume of the latter gas arises from every volume of oxygen which disappears; consequently, a diminution in the oxygen would be accompanied by an increase in the carbonic acid. If, therefore, in one thousand years one per cent. by volume disappeared from the atmosphere, we should find in its stead *a per cent. by volume of carbonic acid*, and this increase would be the more considerable if we reckon the carbonic acid exhaled by volcanoes and other physical processes of the earth, to that arising from animal respiration; but the most accurate investigations have demonstrated that the air does not contain more than about $\frac{1}{25}$ of one per cent. of carbonic acid. It is not unreasonable, therefore, to infer that the plants, a known source of oxygen, restore this gas to the atmosphere. (Graham Otto, vol. II, part 1, page 133.)

The proportion of oxygen in the atmosphere.

Soon after the discovery of oxygen it was supposed that the purity or healthfulness of the air was due to this gas, and hence the process for determining its proportion in the atmosphere was called eudiometry. From the imperfections of analytical processes and instruments, very erroneous conclusions were reached in the early investigations. The atmospheric oxygen was first placed at from 18 to 25 per cent. by volume. Scheele found from 25 to 33, and finally 27. Lavoisier gave at first $\frac{1}{4}$, then $\frac{1}{5}$, for the proportion of oxygen in the air, and subsequently assigned between 27 and 28 per cent. by volume. The first accurate results were obtained in the commencement of the present century by Gay Lussac and Humboldt, at Paris. They found in the air of that city, by twenty-nine experiments with Volta's eudiometer, performed at all seasons and in all weathers, a minimum of 20.9, a maximum of 21.2, and a mean of 21 per cent. by volume of oxygen. Since their researches numerous determinations of oxygen have been made, and we have an accurate knowledge of the composition of the atmosphere. According to the late researches of Bunson, and those of Reiset and Regnault, the percentage of oxygen in the atmosphere is a trifle greater than was at first inferred. Bunson found 20.93 per cent. by volume, and Regnault and Reiset 20.96. If we take their mean, the atmosphere will contain by volume—

Oxygen	20.95
Nitrogen	79.05
	100.00

If we convert these numbers into per cents. by weight by multiplying them respectively by the specific gravity of the gases, we will have for the composition of the atmosphere by weight—

Oxygen	23.16
Nitrogen	76.78
	99.94

Or nearly 100, which demonstrates the accuracy of the numbers expressing the densities of these gases. In view of the important function of the atmospheric oxygen a collection of the actual results obtained by those who have determined its proportion in the air may be deemed not uninteresting.

The following are Th. De Saussure's analyses performed upon air collected upon a meadow at Chambeisy, a league from Geneva, and that from the middle of the Lake of Geneva—(Pogg. Ann. 38, p. 171:)

De Saussure's analyses.

Place.	Day.	Wind and weather.	Oxygen, per cent. by vol.
	1836		
Lake	July 18	Clear; calm	21.08
Chambeisy	August 3	Clear; gentle NE	20.98
Do	August 16	Clear; moderate SW	21.03
Do	August 25	Clear; gentle NE	21.03
Do	August 27	Rainy; very strong SW	21.13
Do	August 27	Rainy; very strong SW	21.15
Do	September 13	Clear; gentle NE	21.08
Lake	September 13	Clear; gentle NE	21.09
Chambeisy	November 5	Cloudy; calm	20.98
Do	November 21	Cloudy; strong NE	21.086
Do	December 13	Calm; foggy	21.006
Do	December 24	Cloudy; strong NE	21.1
Do	December 28	Clear; strong NE	21.0
Lake	December 29	Clear; weak SW	21.04
		Average	21.05

Bunsen's analyses of air establish the accuracy of his process. They differ at the most $\frac{3}{100}$ p. c., and are as follows—(Handwörterbuch der Chemie:)

Table of Bunsen's analyses.

Date.	PERCENTAGE OF OXYGEN BY VOLUME BY—	
	1st analysis.	2d analysis.
January 9	20.973	20.958
January 18	20.928	20.901
January 20	20.923	20.927
January 24	20.921	20.943
January 26	20.927	20.934
January 28	20.928	20.911
January 30	20.889	20.892
February 1	20.840	20.871
February 3	20.925	20.940
February 5	20.937	20.952

Regnault, (Comptes-Rendus, xxvi, pp. 11, 156, 233; also Jour. Pr. Chemie 44, p. 49, and 43, p. 166,) in an extensive series of analyses of air performed at Paris from December 24 to 31, 1847, ascertained the percentage of oxygen to be from 20.9 to 21 by volume; and during January, 1848, from 20.89 to 20.99; and that the analyses of specimens of air taken at different times during the same day gave results which varied within these limits.

The same author (C. R., xxxiv, 863) gives the following results of a number of analyses which, in pursuance of a plan conceived in the year 1848, were performed upon specimens of air collected at noon on the 1st and 15th of each month in as many places as possible. He estimates the error of analysis to be not above 0.02 per cent. From these results Regnault estimates the normal variations of oxygen to be from 20.9 to 21.0; but asserts that in tropical regions it can sink to 20.3.

Table of Regnault's analyses.

Experiments.	OXYGEN PER CENT. BY VOLUME.	
	Minimum.	Maximum.
More than 100 specimens of air from Paris and environs, 1848	20.913	20.999
Nine specimens from Lyons, Montpellier, St. Martin aux Arbres	20.918	20.966
Thirty specimens at Berlin, 1848–'49	20.908	20.998
Ten specimens at Madrid, 1848	20.916	20.982
Twenty-three specimens at Genoa, Mont Saleve, and Mont Buet	20.909	20.993
Fifteen specimens at roadstead of Toulon, Mediterranean Sea, and Algiers harbor	20.912	20.982
Five specimens, passage from Liverpool to Vera Cruz	20.918	20.965
One specimen at Gullalamba, Ecuador	20.960	....
Two specimens at Pichincha—higher than Mont Blanc	20.949	20.988
Average oxygen in Paris and environs	20.96	....
Twenty-nine specimens of air collected by Ross in the polar seas in 1848–'49	20.9	....

Stas (Jr. Pr. Chemie, xxvi, p. 297) performed at Brussels twelve analyses of atmospheric air collected at different times, and obtained a percentage of oxygen (by weight) which varied from 23.04 to 23.08. On two occasions, without knowledge of any error, he found 23.11 and 23.14. He thus found the composition of the air of Brussels to be the same as that of Paris, Geneva, and Copenhagen, and confirmed the observation

made at Paris, that, from some unknown cause, sudden changes at times modify the composition of the air.

Boussingault (Ann. de Ch. et de Phys., series 3, vol. iii, p. 281) determined the oxygen at different elevations and obtained the following average results:

Boussingault's analyses.

Locality.	Elevation above the sea, in meters.	Percentage of oxygen, by volume.
Santa Fé de Bogota	2, 650	20. 65
Ibaqué	1, 323	20. 70
Mariquita	548	20. 77
Average		20. 70

The following table comprehends the results of Dumas and Boussingault. (Ann. de Ch. et de Phys., 3, III, 304.) The experiments were performed at Paris with different wind and weather:

Table of Dumas's and Boussingault's analyses.

Day.	Barometer, *m.m.*	Thermometer, C°.	Wind.	Sky.	Oxygen, p. c., by weight.
April 27, 1841	759. 5	23	S.	Clear	22. 92
April 28, 1841	758. 3	25°	SE.	Clear	23. 06
April 29, 1841	757. 6	27°	NW.	Clear	23. 03
May 29, 1841	759. 7	17°4	N.	Rain	23. 01
July 20, 1841	753. 9	19°	S.	Rain	23. 00
July 21, 1841	752. 1	14°7	SW.	Clear	23. 00
July 24, 1841	758. 2	17°8	N.NW.	Clouded	23. 08
September 20, 1841	758. 9	22°6	N.	Clear	23. 07
September 22, 1841	751. 2	21°	S.SW.	Clouded	22. 89
Average					23. 007

The following simultaneous analyses of air were performed at different places—(Ann. de Ch. et de Phys., 3, III, 301:)

Table.

A. At Paris, by Dumas and Boussingault. Garden of Dumas's laboratory.

Day.	Hour.	Weather.	Oxygen, per cent., by weight.
July 20, 1841	1½ to 5 p. m	Sky clouded; rain during experiment	23. 05
July 21, 1841	11½ p. m	Sky clear	23. 00
July 24, 1841	10 a. m. to 2 p. m.	Sky clear; no wind	23. 07
		Average	23. 04

B. At Berne, Switzerland, by Brunner.

Day.	Hour.	Weather.	Oxygen, per cent., by weight.
July 20, 1841		Slightly cloudy; west wind	23.00
July 21, 1841	11 p. m	Sky cloudy	22.89
July 24, 1841	7 to 8 a. m	Clear	22.97
July 24, 1841	7 to 9 p. m		22.96
		Average	22.95

C. Faulhorn Mountain, Switzerland, by Martin and Bravais. This air was taken at the "*Hospice*," twelve meters below the summit of the mountain, and 2,683 meters above the sea level.

Day.	Hour.	Weather.	Oxygen, per cent., by weight.
July 20, 1841	9 a. m	Clear, fine 36 hours	22.96
July 21, 1841	6 to 11 p. m	Cumuli over the whole sky	23.10
July 24, 1841	7 to 8 a. m	Snow previous night—fog	22.95
July 24, 1841	6 to 7 p. m	Fog disappearing, wind southwest	22.85
August 7, 1841	4 to 4½ p. m	Sky clear for 48 hours	22.97
		Average	22.97

Laskowski (Ann. de Ch. et de Pharmacie) examined the air of Moscow during the cholera epidemic from November 3 to 11, 1847, and found by 14 experiments from 20.73 to 20.89 volume per cent. of oxygen, and a mean of 20.82.

Dumas (Comptes Rendus XIV, 379) communicated to the French Academy the following results obtained by several chemists who had zealously devoted themselves to the analysis of the following atmosphere:

Table of Marignac's analyses.

A. Marignac, Geneva, 1842.

Date.	Per cent., by weight.
January 11	23.01
January 18	23.00
February 3	22.97
Average	22.98

B. Lewy, at Copenhagen.
I. In the court-yard of the Polytechnic Institute.

Date.	Time.	Weather.	Oxygen, per cent., by weight.
November 17	4 p. m	Snow	23.00
November 30	M	Clouded	23.02
December 12	10.30 a. m	Clear	22.96
December 15	12.30 p. m	Clear	22.99
December 22	11.30 a. m	Snow	23.01
		Average	22.996

II. Air at sea, (the Baltic.)

Day.	Time.	North latitude.	West longitude, from Paris.	Oxygen, per cent., by weight.
August 4	8.30 a. m.	57 56	8 22	22.57
August 3	10.45 a. m.	55 30	5 30	22.58
August 2	1 p. m.	52 36	0 58	22.59
August 3	1.15 a. m.	54 15	2 7	22.56
Average				22.575

III. Analysis of air from the sea-coast, with a sea wind, at 35 feet above the ocean level. Air received at the Fortress Kronburd, 12 miles from Copenhagen.

Day.	Time.	Weather.	Wind.	Oxygen, per cent., by weight.
February 18	9.30 a. m.	Clouded	NE.	23.02
February	do.	do	NE.	23.01
February	do.	do	NE.	23.02
Average				23.016

The mean of the results at Geneva is exactly the same as that obtained at Paris.

The air of Copenhagen has also the same composition. The sea air contains less oxygen at the ocean level, but at an elevation of 35 feet it possesses the same composition as that of the interior of the country.

Verver found in the air of Gröingen 22.938 per cent. by weight of oxygen.

The contamination of the atmosphere by the products of human life and industry in cities does not diminish to a serious extent its proportion of oxygen. This is shown by the following experiments of Dr. R. Angus Smith (Qr. Jour. Chem. Soc., xi, 299) upon the air of Manchester. The diminution of oxygen constitutes from 0.1 to 0.2 per cent. by volume, although with gusts of smoke it may be greater.

Table of the air of Manchester, by Dr. Angus Smith.

Specimen No.	Remarks.	Oxygen, per cent., by volume.
1	Air collected at different times in Manchester	20.868
2		20.179
3		20.807
4		20.613
5		20.793
	Mean of numbers 1, 3, 4, and 5	20.770

The following table (compiled from Gmelin's chemistry) comprises the results of observations upon the atmospheric oxygen made by different analyses. Some of the numbers appear to be inadmissible: I quote them, however, for the sake of the general view of the subject:

Table of oxygen analyses by various observers.

Observer.	Remarks.	Oxygen, per ct. by volume.
Berthollet	In Cairo and in Paris	Nearly 22.0
De Marty	Catalonia, under all circumstances and in inhabited rooms	21–22
Sir H. Davy	Bristol, other parts of England, on the coast, at sea and in air, from the coast of Guinea.	21
Berger	Jura, mountains and valleys of Savoy, upon the glaciers and in the Wallis Valley.	20.3–20.65
Configliachi	Simplon, Mt. Cenis, and other Alps	21
Do	Upon marshes	21
Do	Upon rice fields	20.8
Do	In confined places	20.3
G. Lussac and Humboldt	Paris, under all circumstances	20.9–21.1
Gay Lussac	In Paris, and at 6.636 meters above the earth in a balloon	21.49
A. Vogel and Krüger	Over the Baltic Ocean.	20.59
Hermbstädt	On the coast of the Baltic Ocean, 5 feet above its level	21.5
Do	On the coast of the Baltic Ocean, 16 feet above its level	20.5
Do	In the country	20.0
Marchand	From 10 analyses of air, from 20.9–21.03 mean	20.97
Dalton	In England, usually	20.7–20.7
Do	In England, occasionally	21
Do	In England, maximum January 8, 1825, wind N. E.	21.15
Do	In England, air, from Helvellyn, 3,000 feet high	20.64
Do	In England, Manchester	20.99
Do	In England, Helvellyn	20.63
Do	In England, Manchester	20.73
Do	In England, Snowdon, 3,570 feet elevation	20.70
Do	In England, from the plain, three miles from Manchester	20.85
Do	In England, air collected in a balloon, by Grafton, 9,660 feet high.	20.70
Do	In England, Manchester	20.83
Do	In England, air, by Green, balloon 15,000 feet high	20.62
Do	In England, Manchester	20.95
Do	Air, from Mer de Glace Chamounix, 6,000 feet high	19.80
Do	Air, from Simplon, 6,174 feet high	19.76
Do	Air, from Wengern Alp, 6,230 feet high	20.28
Th. Thompson	In Glasgow, average of numerous experiments	21.01
Kupffer	In the air of Kasan	21–21.2
Brunner	In Switzerland, in the valley	21.07
Do	In Switzerland, lakes	20.85
Do	In Switzerland, upon the Faulhorn	20.915
Green	Air, by a balloon, 11,300 feet high	21
Baumgartner	Air, in Vienna, during the cholera	20.4–21.4
Schiel	In the air of the prairies of North America: elevation above ocean 2,330 feet.	0.91

From these results we perceive, first, that the normal proportion of oxygen in the atmosphere has been determined with very considerable precision; and, second, that an analysis determining the amount of this gas in the air of an inhabited apartment will afford no data for estimating the character of its ventilation.

II. ANALYSES DETERMINING THE CARBONIC ACID IN THE ATMOSPHERE.

More important, for the purposes of this research, is the question of the proportion of carbonic acid in the air. This gas, when present in excess, is poisonous to animal life. It accumulates in inclosed places by the breathing of men and animals when not removed by the introduction of fresh air.

The proportion of carbonic acid which is actually injurious to life is unknown, and there is much difference of opinion as to how much can be borne with safety; probably a very small excess over the normal quantity in the atmosphere would prove hurtful if it acted continually upon the system. Hence it becomes important, where there is a question of ventilation, to ascertain the normal quantity present in the atmosphere, and to increase the ventilation as near to that point as may be consistent with other effects to be produced, such as warmth, absence of currents, and the like. I proceed to give the results of analyses of the atmosphere, and of the air of inhabited rooms, so that we may be able to compare them with similar results which I have obtained in Washington.

From the healthful nature of country air when compared with that of cities, we might expect to find a *much* smaller amount of carbonic acid in the air of the former compared with that of the latter; but experiments do not warrant this assumption, and we must assign the insalubrity of cities to other causes.

Dr. R. Angus Smith (Quarterly Jour. Chem. Soc., xi, 196) has shown this by an extended research into the air of towns, selecting for his experiments a city of which the air should be much contaminated by the results of human industry.

This locality is Manchester, England, with its environs, a district comprehending many hundred square miles, every portion of which is influenced by the smoke of manufactories consuming bituminous coal, and of which we have not the like in any portion of our own country. Dr. Smith says that the tinge of darkness in the atmosphere, arising from the smoke, may be seen making a line of at least forty miles in length, and affecting vegetation injuriously, (by the deposition of carbon;) thus influencing the character both of the sky and of the landscape.

Two millions of tons of coal are burned annually in this city. It is interesting to calculate the amount of carbonic acid gas which the combustion of this coal would add to that arising from the breath of the inhabitants, and that normally present in the atmosphere. Dr. Smith supposes that the smoke may influence the air to an elevation of 600 feet, and gives the following estimate of its effect upon the atmosphere:

	Carb. acid, per cent. by volume.
On a space of 16 square miles, 60 feet high, the consumption of this amount of coal yields the following	1.6499
The amount already in the air is, say	0.06
Suppose that 400,000 inhabitants exhale 266 cubic feet of air, containing 6 per cent. of carbonic acid, there would be 330 tons, or volumes per cent	0.0362
Hence in the air there would be	1.7461

If this were changed ten times per day, the per cent. of carbonic acid in the air, at any given period, would be—

From coal	0.16499
From breath	0.00362
The normal quantity	0.06
	0.22861

If changed 20 times, we would have—

From coal	0.08248
From breath	0.0018
Normal	0.06
	0.14428

But assuming the height influenced to be 300 feet instead of 60, and the air to be changed ten times, then we would have—

From coal	0.033
From breath	0.00072
Normal	0.06
	0.09372

By the observations of Mr. Hartnup, the air at Liverpool has an average speed of 12.62 miles per hour. If we suppose it to be 12 miles at Manchester, it would sweep over four miles thirty-six times in twelve hours. This would give, for a height of 30 feet, of carbonic acid—

From coal	0.0091
From breath	0.0002
Normal	0.06
	0.0693

And assuming the air outside of the city to contain 0.03 per cent. of normal carbonic acid, we would have then—

From coal	0.0091
From breath	0.0002
Normal	0.0300
	0.0393

The last results accord, as well as can be expected, with the following analyses by Dr. Smith. The analyses were effected by drawing a known quantity of air through tubes containing substances capable of depriving it of moisture and carbonic acid. The weather was remarkably open and fine, and the results were sometimes lower than those calculated for the air in the country. When much wind is blowing they average from 4.5 to 8, and with little wind from 10 to 12 volumes of carbonic acid in 10,000 of air.

Table of Dr. Angus Smith's analysis.

No. of analysis.	Locality.	Cubic feet of air tested.	Carbonic acid, per 10,000 volumes of air.
1	Literary and Philosophical Society, Manchester	14.63	4.09
2	....do..........do.........do.........do	9.2	5.73
3	....do..........do.........do.........do	5.0	4.55
4	....do..........do.........do.........do	4.6	15.44
5	....do..........do.........do.........do	6.91	5.44
6	....do..........do.........do.........do	5.38	11.95
7	....do..........do.........do.........do	2.256	9.73
8	....do..........do.........do.........do	2.98	9.72
9	....do..........do.........do.........do	4.6	5.75
10	....do..........do.........do.........do	3.83	6.68
	Average		7.908
11	Hills near Preston		2.2
12	At Blackpool		3.0
	Hence, increase by smoke, &c., in Manchester		4.9

The following table contains additional results obtained by Smith by a method of analysis in which manganate of potassa was employed in determining the carbonic acid. This method has not been sufficiently tested to warrant confidence in its accuracy, although the results accord pretty well with each other.

Table of analyses, (Dr. R. A. Smith,) in which manganate of potassa was employed.

No. of analyses.	Date.	Locality.	Weather.	Carbonic acid per 10.000 vols. air.
1st series.				
1		Manchester		9.81
2		do		10.12
3		do		9.55
4		do		8.99
5		do		9.27
6		Closed and crowded railway carriage		34.84
2d series.				
1	May 17	At laboratory, Manchester	Very wet day; wind blowing toward the city.	5.22
2	do	do	do ... do	5.46
3	do	do	do ... do	5.70
4	do	do	do ... do	5.64
5	do	do	do ... do	5.88
6	do	do	do ... do	5.83
7		Other side of the town, wind blowing violently, allowing no circulation.	Very dry and clear day	6.79
8	May 18	do ... do	do	9.37
9	do	do ... do	do	7.09
10	do	do ... do	do	7.09
11	do	Manchester, at Oldham road, where much carb. acid might be expected.	Very wet day	7.17
12	do	do ... do	do	7.21
13	do	do ... do	do	6.71

The elder De Saussure observed the presence of carbonic acid in the atmosphere of the summit of Mont Blanc, in the region of continual snow. The younger De Saussure investigated, at Geneva, the proportion of this gas in the air, in a research which has become classical, and of which the results are accepted yet as among the most, if not the most, accurate of any which we possess.

The following table (Pogg. Annalen, xix, p. 426) comprises some of the results of Th. De Saussure's analyses, quoted by Dr. Gilm, (K. Acad., Wien, xxiv, p. 279:)

Table of De Saussure's analyses.

	Car. acid in 10,000 vols. of air.
1827—November 6	4.06
1827—November 14	4.16
1827—November 21	3.91
1827—December 5	4.06
1827—December 22	4.18
1827—December 27	4.13
1830—January 3	4.79
1829—January 28	4.26
1829—February 21	3.66
1827—February 19	3.58
1829—February 19	4.26
1829—March 7	4.25
1829—March 12	4.25
Average	4.12

De Saussure's experiments extended over the years 1827–'29, and embraced the number of 225 analyses. They were performed at Geneva, and on the estate of the author, at Chambeisy, a village lying upon a dry, airy meadow, (with clay soil,) 16 meters above Lake Geneva, and ¾ of a league distant from the city of the same name. Comparative experiments were also made upon the air of the lowlands and that of the mountains.

The following compend of the results of these most interesting experiments (Handwörterbuch der Chemie Poggendorf, Liebig, &c.; art. Atmosphere) illustrates their value:

Compend of Th. De Saussure's analyses.

In Chambeisy, four feet above the ground, the amount of carbonic acid, at all times and seasons, deduced from 104 analyses, is—

	Car. acid per. 10,000 vols.
Minimum	3.15
Maximum	5.74
Mean	4.15

By separating the results by day and night, we have, by day—

Minimum	3.15
Maximum	5.40
Mean	3.38

And by night, viz:

Minimum	3.21
Maximum	5.74
Mean	4.32

From which it appears that the amount by day is less than by night. At noon the carbonic acid was lower with a gentle than with a strong wind; thus—

With a gentle wind, mean	3.76
With a strong wind, mean	3.98

The effect of rain could not be determined by comparing the results at Chambeisy with those obtained simultaneously at Geneva, because, with much rain in Geneva a smaller amount of carbonic acid was found at Chambeisy, and inversely. De Saussure considers the uniform moistening of the ground by gentle rain more productive of carbonic acid than by a strong rain. It acts by cooling the ground. Frost also increases the carbonic acid.

Thirty six comparative experiments at Chambeisy and in the middle of Lake Geneva, four feet above its level, gave—

For Chambeisy, mean	4.60
For the lake, mean	4.39
For the lake, minimum	3.42
For the lake, maximum	5.78

Thirty comparative experiments between the air of Chambeisy and that of a street in Geneva yielded—

For Geneva	4.68
For Chambeisy	4.37

The day observations gave the above results: those of the night yielded a smaller proportion for the town than for the country.

Finally, De Saussure observed that the proportion of carbonic acid was greater on the tops of mountains than in the plains or valleys, as may be seen from the following. (Pogg. Ann., xix, 422, and Karsten, Alg. Encyk. d. Physik Lieferung. iii, p. 26. Meteorologie:)

Table of De Saussure's analyses. (Carbonic acid on mountains.)

Locality.	Metres above ocean.	July 20, 1827—12 m.	June 28, 18[illegible]—12 m.	May 25, 1829—m.	July 14, 1829—11 h.	July 15, 1829—12 h.	Aug. 7, 1829—11 h.	Aug. 8, 1829—12 h.	Sept. 29, 1829—11 h.	Sept. 30, 1829—12 h.
Chambeisy, Lake Geneva	388	4.74	4.46	......	4.14	4,15	3.87	3.22	3.55	3.15
Col de la Faucille, Jura	963	......	......	......	4.43	4.54	3.69	3.60	4.22	3.95
Summit of the Dôle	1,267	4.91	4 91	......	......	......	......	......	......	......
Chambeisey	388	......	......	4.13	......	......	......	......	......	......
Cologne, base of Salève	......	......	......	3.67	......	......	......	......	......	......
Grand Salève-sur-Grange Tourmès	945	......	......	3.59	......	......	......	......	......	......

Chambeisy, 1829, May 25, m., 388 meters	4.13
Cologne, base of Salève, 1829, May 25, m.	3.67
Grand Salève-sur-Grange Tourmès, 1829, May 25, m., 945 meters	3.59

By the side of these experiments of Saussure, showing that the proportion of carbonic acid is greater in the more elevated regions, (as Gay Lussac also found was the case by experiments upon air collected during his aerostatic journey,) may be placed those of Messrs. Schlagintweit.

These chemists investigated the air of the Alps. H. and A. Schlagintweit (Pogg. Ann., lxxvi, 442) found that in the air of the eastern Alps the carbonic acid increased progressively, according to the elevation, to 3,366 meters, which height they believe to be the limit of a constant maximum. Their results yielded from 3.2 to 5.8 per 10,000 volumes.

A. Schlagintweit, (Pogg. Ann., lxxxvi, 293,) in an examination of the air of the Western Alps, in the neighborhood of Monte Rosa, confirmed the above results. At the height of from 3.162 to 4.224 meters, when the air was clear, it contained a mean amount of 7.9, and a maximum quantity of 9.5 carbonic acid. When the place of observation was enveloped in a dense cloud, which extended to the lower valleys, the proportion of carbonic acid sank to 5.9. At Berlin (elevation 32.5 meters) S. found by three observations 3.9 to 4.5 carbonic acid. The following table gives the details of these results:

Table of Schlagintweit's analyses.

Date.		Locality.	Meters elevation.	Weather.	Wind.	Carb. acid, p'r 10,000 volumes.
1848. (?)		*Eastern Alps.*				
Aug.	18	Lienz	752	On 17th, p. m., storm	NW	4.2
	20	Johannis Hutte	2, 461	Fog near	SE	4.8
Sept.	4	Rachern	3, 366	Clear	NW	5.8
	6	Johannis Hutte	2, 478	Slight cirri	NW	4.7
	6	Pasterze	2, 449	Clouds in the west	E	3.2
	9	Heiligenblut	1, 308	Slight rain	SW	4.1
1851.		*Western Alps.*				
Sept.	18	St. Jean de Gressoney, Piedmont.	1, 370	Cloud to the tree line and continual rain.	SE	4.97
Aug.	19	Zermatt, Wallis	1, 652	Cloudy; rainy	E. NE.	4.80
Sept.	17	Bödemie, Piedmont	1, 925	Thick clouds; light rain	SE	4.75
	4	Vincent Hütte, Monte Rosa	3, 162	Occasional cloud and fog	NE	7.53
	5	do	3, 162	Half clear	SW	7.30
	5	do	3, 162	Thick clouds	E	5.94
	6	do	3, 162	Clouded; misty	NE	8.81
	8	do	3, 162	Occasional cloud and fog	NE	8.29
	10	do	3, 162	Thick clouds	NE	6.34
	14	do	3, 162	Thick clouds, but little broken	SE	6.64
	15	do	3, 162	Very clear	N	9.51
Aug.	25	Matterjoch	3, 353	Occasional clouds 1,000 to 1,500 feet above the mountain.	SW	9.16
Sept.	12	Vincent pyramid	4, 224	Very clear	E. NE.	9.32
June	9 to 21.	Berlin	32.5	Half clear	W	1.22
		do	32.5	Clear	W	3.90
		do	32.5	Clear	W	4.53

The following are some of the results obtained by other observers upon the proportion of carbonic acid in the atmosphere:

Table of carbonic acid results.

Observers.	Remarks.	Carb. acid in 10,000 volumes.
Verver	In 90 experiments, mean	4.188
Verver	In 90 experiments, maximum	5.05
Verver	In 90 experiments, minimum	3.57
Brunner	In air of the country, mean	5.00
Dalton	In the atmosphere	6.5
Coutigliachi	In the atmosphere	8.0
Humboldt	In the atmosphere	5.0
A. Vogel	In the air of the Baltic almost none (?)	0.0 (?)
Emmet	In the air of the Atlantic always, and at Bermuda	1.25
Beauvais	Air collected from a balloon	5.0
Marchand	Jour. Pr. Ch., xliv, 24. Mean of 150 analyses	3.1
A. Vogel, jr	Air of Munich during cholera, August 10–20, 1854	3 to 4

Frankland (Qr. Jour. Chem. Soc., xiii, 22) found the following to be the composition of the air in Switzerland at different elevations upon Mont Blanc:

Table of Frankland's analyses.

Locality.	Feet above the level of the ocean.	In 10,000 vols. of air.	
		Oxyg	Carb. acid.
Chamounix	3,000	2089.4	6.3
Grand Mulets	11,000	2080.2	11.1
Summit of Mont Blanc	15,732	2096.3	6.1

Méne has published the results of numerous experiments upon the carbonic acid of the atmosphere, (Comptes Rendus, xxxiii, pp. 39, 222; xxiii, p. 39; lvii, 155, &c.) He gives the same amount of carbonic acid in the air for the months of December and January. From February to May it increases; from June to August it diminishes, and from September to November it increases again; so that in October the air is richest in this constituent. During the night the carbonic acid is less than in the daytime. During the day there is a slight increase toward noon. After a rain the carbonic acid increases.

The following are Méne's experiments upon the atmosphere in Paris, tested at different elevations upon the Pantheon. Méne infers that at a certain elevation there is less carbonic acid than at the surface of the ground.(?)

Table of Méne's experiment.

Date.	Time of experiment.	Carbonic acid per 10,000 vols. of air.
August 4, 1851	8 to 9 a. m	3.4
August 4, 1851	M. to 1 p. m	4.2
August 4, 1851	5 to 6 p. m	2.7
August 5, 1851	8 to 9 a. m	1.2
August 5, 1851	M. to 1 p. m	2.7
August 5, 1851	4 to 5 p. m	2.9
August 6, 1851	7 to 8 a. m	1.32
August 6, 1851	M. to 1 p. m	3.6
August 6, 1851	7 to 8 p. m	2.99
August 7, 1851	8 to 9 a. m	1.25
August 7, 1851	1 to 2 p. m	3.4
August 7, 1851	5 to 6 p. m	1.12
	Average	2.315

Henry H. Watson (Rep. 4th meeting British Association, p. 583) made an extensive research upon the atmospheric carbonic acid in Bolton, England, and in the neighborhood, from which he inferred the air of the city to be richer in that gas. The method of analysis employed is similar to that proposed by Pettenkoffer. A solution of lime-water was used for absorption; the strength of the solution in lime, before and after the absorption, being determined by sulphuric acid.

The following table embraces his results.

Horrock's Moor lies three miles to the northwest from Bolton, and is by barometric observation 544 feet higher.

Winter Hill is between five and six miles northwest from Bolton, and 1,214 feet higher. The west and northwest winds blow from the sea.

Watson does not agree with De Saussure in finding uniform differences corresponding to the different seasons and dry or wet weather, and attributes the actual differences in this respect rather to the unavoidable errors of analysis.

Table of analyses by Watson.

Locality.	Time.	Weather. At time of experiment.	Weather. Before experiment.	Wind.	Temp., Fahr.	Carb. acid in 10,000 volumes.
	1832.				°	
Bolton, England	September 28, 5h. 30m. p. m	Fair	8 fair days			5. 282
Do	October 5, 1h. p. m	Rain	1 fair day		53	5. 282
Do	October 11, 10 a. m. to 3 p. m	Rain	4 wet days		60	5. 282
Do	October 13, M	Rain	6 wet days		57	4. 448
Do	December 31, M	Rain	8 rainy days		38	5. 282
	1833.					
Do	February 2, 10 p. m	A little rain	1 fair day		35	5. 559
Do	March 9, 3h. 30m. p. m	Snow	2 fair days			5. 000
Do	April 30, 6h. 30m. a. m	Fair	4 rainy days		38	8. 620
Do	May 7, M	Fair	3 fair days		75	5. 000
Do	May 9, 2 p. m	Fair	5 fair days		74	4. 196
Do	May 11, midnight	Fair	2 wet days		54	5 559
Do	May 15, 6h. 30m. a. m	Rainy	1 fair day		60	4. 739
Do	May 18, midnight	Fair	1 wet day		56	6. 393
Do	May 29, M	Fair	9 fair days		51	5. 838
Do	June 4, 9 p. m	Rainy	2 wet days		57	4. 196
Do	June 11, 10 p. m	Rainy	1 fair day		58	4. 196
Do	July 23, 1h. 30m. p. m	Rainy	5 wet days		46	5. 000
Do	September 24, 8h. 30m. p. m	Rainy	1 fair day			6. 393
Do	December 14, M	Rainy	1 wet day			4. 440
	Average of 19 experiments					5. 300
	1833.					
Horrock's Moor	August 1, 7h. 30m. p. m	Fair	2 fair days	N	61	3. 890
Winter Hill	August 8, 3 p. m	Fair	2 fair days	W	55	4. 448
Horrock's Moor	September 6, 2h. 30m. p. m	Fair	1 fair day	E	65	4. 739
Do	September 14, 3 p. m	Rainy	3 wet days	N	62	3. 890
Do	October 2, 3 p. m	Fair	2 fair days	N.NW	60	4. 196
Do	October 24, 3. p. m	Rainy	6 wet days	S. SW	52	4. 448
Do	November 6, 2 p. m	Rainy	4 wet days	W*	46	3. 614
Do	December 6, 2h. 30m. p. m	Rainy	9 wet days	W*	40	3. 614
Winter Hill	December 25, 1 p. m	Fair	12 wet days	N.NW	34	4. 196
	1834.					
Horrock's Moor	January 2, 2h. 30m. p. m	Fair	7 wet days	N	31	4. 196
Do	January 30, 2h. 30m. p. m	Rainy	1 fair day	SE	41	†4. 196
Winter Hill	February 11, 2h. 45m. p. m	Fair	2 wet days	W	40	4. 196
	Average of the above 12 analyses.					4. 135

* Very strong wind. † Air taken during a thick fog.

Gilm (Sitzung's Bericht des Math. Natur. Classe des K. Acad. Wein. xxiv, 279) has given a number of analyses of the air, drawn from a garden at Innsbruck, according to his process, which has been described in a former page of this report. In these analyses he employed thirty liters of air, which passed through the apparatus in three hours. In testing the accuracy of his method, he determined by it the amount of carbonic acid liberated from 0.2 gram of carbonate of baryta, with the following satisfactory result:

Carbonic acid.

Calculated 0.0449 — obtained by experiment:	I. 0.0427
	II. 0.0455
	III. 0.0462
	IV. 0.0446
Mean	0.04475

Table of Gilm's determinations of carbonic acid.

Time.	Weather.	C'rbonic acid in 10,000 vols. of air.
November 18, 1856	Clear, cold	3.89
" 19, 1856	Calm, cloudy	3.83
" 22, 1856	Rain	4.30
" 29, 1856	Cloudy	4.33
December 2, 1856	Clear	4.53
" 5, 1856	Clear, cold	4.39
" 11, 1856	Sirocco	4.19
" 17, 1856	Clear, cold	4.15
January 2, 1857	Slightly cloudy	4.58
" 15, 1857	Snow	4.03
" 17, 1857	Clear	4.16
" 21, 1857	Clear	4.11
" 27, 1857	Slight clouds	4.10
February 6, 1857	Clear	4.38
" 12, 1857	Snow	4.31
" 17, 1857	Clear	4.35
" 22, 1857	Clear, calm	3.85
" 23, 1857	Sirocco	3.85
March 7, 1857	Clouded snow	3.82
Mean		4.15
Maximum		4.6
Minimum		3.8

Lewy (Comptes Rendus, xxxiii, 345; Jour. Pr. Ch., liv, 249, &c.) has made an extended research upon the atmospheric carbonic acid and oxygen, comparing the results obtained in Europe with those of the air of the Atlantic Ocean and of South America. He employed the analytical method of Regnault and Reiset. He found that the greatest difference between two analyses never amounted to more than [illegible], and most frequently $\frac{1}{10000}$.

The mean of analyses performed at eleven different places in New Granada yielded for normal air per 10,000 volumes:

Carbonic acid	4.008
Oxygen	2101.425
Nitrogen	7894.555

This result agrees with his observations upon the atmosphere of Europe.

The variations which he detected in the constituents depend upon the meteorological conditions. Thus, after a long rainy season there was less carbonic acid and oxygen than after a prolonged dry season. For example, by the examination of a large number of specimens of normal air of Bogota he found:

Atmospheric air.	During the rainy season, cloudy sky.	During the dry season, clear sky.
Carbonic acid	3.822	4.573
Oxygen	2099.542	2102.195
Nitrogen	7896.630	7893.232
In volumes of air	10000.000	10000.000

This demonstrates a difference, in favor of the dry season, of 0.751 carbonic acid, and 2.653 oxygen.

Taking the maximum and minimum of his results for the two seasons respectively, he found:

Atmospheric air.	Minima for the rainy season.	Maxima for the dry season.
Carbonic acid	3.609	5.043
Oxygen	2099.032	2103.199
Nitrogen	7891.758	7891.758
In volumes of air	10000.000	10000.000

The greatest difference, therefore, amounts to 1.434 for the carbonic acid, and 4.167 for the oxygen. These differences, he states, are almost the same as those found at Paris in meteorological conditions corresponding to the dry and rainy seasons of South America.

New Granada afforded Lewy very interesting results as to abnormal conditions of the air. During the extensive conflagrations for agricultural purposes, called *las quemas*, he discovered as much as 49 volumes of carbonic acid per 10,000 of air, the oxygen having at the same time experienced a diminution of 68.35 per 10,000. In the city of Santa Fe de Bogota he found at times an enormous quantity of carbonic acid in the air, which he attributes to volcanic agencies. Thus in 1850, during the months of May to July, the air contained from 3 to 4, and in the month of August the large quantity of 47 volumes of carbonic acid per 10,000; and he asserts that he is fully convinced of the accuracy of his method of analysis.

At sea Lewy discovered a larger proportion of carbonic acid and oxygen in the air by day than at night—a difference equal to 2.07 for the carbonic acid, and 9.96 for the oxygen. He attributes this to the action of the sunlight upon the ocean, liberating the gases which it holds in solution, and which are richer in oxygen and carbonic acid than atmospheric air. Thus, in air taken at a distance of four hundred leagues from the coast, upon the same day and with the same wind, he found:

Atmospheric air.	At 3 a. m.	At 3 p. m.
Carbonic acid	3.346	5.420
Oxygen	2096.139	2106.099
Nitrogen	7900.515	7888.481
In volumes of air	10000.000	10000.000

The following table, compiled by E. E. Schmid (Art. Meteorologie, Karsten's Encyklopädie des Physik) from the Annales de Chimie et de Physique, 3d ser., vol. xxxiv, comprises the results of Lewy's interesting research:

Table of Lewy's analyses of the atmosphere.

1. AIR OF GUADELOUPE.

(Dry air, per 10,000.)

Guadeloupe.	Elevation above ocean.	Sky.	Wind.	Temperature C.	1842.	Carb. acid, per volume.	Oxygen, weight.	Nitrogen, weight.
	Meters.				*h. m.*			
Plantation Deville, by the small canal.	25	Clear	E.NE.	28.9	Nov. 20, 0 30 p. m ..	147.6	2304	7696
	25	...do	..do ...	28.9	Nov. 20, 0 30 p. m ..	143.9	2302	7698
	25	Very clear.	..do ...	24.8	Nov. 21, 0 30 p. m ..	14.4	2305	7695
	25	Clouded...	NE ...	27.3	Nov. 23, 0 45 p. m ..	51.0	2314	7686
	25	Clear	Calm .	24.4	Nov. 23, 11 45 p. m ..	89.0	2285	7715
	25	...do	SE ...	29.5	Nov. 27, 2 00 p. m ..	2.6	2304	7696
Mangroves of the river Salee.	0	Very clear.	Calm .	22.5	Nov. 28, 0 45 p. m ..	9.8	2267	7733
	0	....do	..do ...	22.5	Nov. 28, 0 45 p. m ..	9.2	2269	7735
	0	....do	E.NE.	21.8	Nov. 29, 11 40 p. m ..	39.0	2300	7700
Plantation Petit Bourg.	25							

2. IN FRANCE.

(Dry air, in 10,000 volumes.)

Locality.	Winds.	Sky.	Temperature, C.	1847.	Carbonic acid.	Oxygen.	Nitrogen.
			°	h. m.			
Paris	W	Cloudy	15.5	Sept. 6, 12 30 a. m.	5.144	2101.356	7893.500
Havre	W	Very cloudy.	10	Nov. 22, 8 45 a. m.	3.588	2088.783	7907.629

3. UPON THE ATLANTIC OCEAN.

North latitude.	West longitude, (Paris.)	Distance from coast.	Sky.	Wind.	Temperature, C.	1847.	Carbonic acid.	Oxygen.	Nitrogen.
° ′	° ′	Leagues			°	h. m.			
47 30	10 5	55	Cloudy	E.SE.	16.0	Dec. 1, 11 30 a. m.	4.881	2015.170	7839.949
47 0	13 0	120	Clear	NW	23	Dec. 4, 3 00 a. m.	3.338	2096.321	7900.341
35 40	20 35	190	A little cloudy	NE	17.5	Dec. 8, 12 15 a. m.	5.497	2105.945	7888.558
22 5	39 0	400	Clear	NE	23	Dec. 17, 3 00 p. m.	5.771	2106.030	7888.199
21 45	41 3	435	....do	E	21.5	Dec. 18, 3 00 a. m.	3.346	2096.139	7900.515
21 9	42 25	412	A little cloudy	E	24	Dec. 19, 3 00 p. m.	5.420	2106.099	7888.481
20 35	43 35	390	Clear	E	22	Dec. 19, 3 00 a. m.	3.388	2096.074	7900.538
15 49	64 28	80	....do	E	27.2	Dec. 26, 1 00 p. m.	5.288	2105.889	7888.823
14 6	70 4	60	....do	E	27	Dec. 28, 2 15 p. m.	5.093	2105.686	7889.221
12 5	76 0	15	....do	NE	25.5	Dec. 30, 12 30 a. m.	5.143	2105.789	7889.068
......	......	1—2	....do	E	24	Dec. 31, 3 00 a. m.	3.767	2101.114	7885.119

4. IN SOUTH AMERICA.

(Dry air, per 10,000, per volume.)

Locality.	Elevation.	Sky.	Wind.	Temperature, Celsius.	1848.	Carbonic acid.	Oxygen.	Nitrogen.
	Meters.				h. m.			
Santa Marta	0	Clear	E	31.5	Jan. 25, 12 00 a. m.	4.616	2102.379	7893.005
Mompox	38	....do	E. NE.	32.5	Feb. 7, 3 25 p. m.	3.147	2104.936	7891.917
Rio Magdalene	......	Cloudy	E. NE.	29.5	Feb. 18, 4 30 p. m.	3.259	2103.222	7893.519
Do	......	Clouds	E. NE.	24.5	Mar. 3, 2 45 a. m.	4.554	2099.826	7895.620
Honda	242	Very cloudy	Calm	26.0	Mar. 29, 3 00 a. m.	3.226	2099.237	7897.537
Ambalema	282	Clear	E	30.0	Aug. 5, 12 30 a. m.	11.203	2054.833	7933.964
Esperanza	396	....do	E. SE.	26.5	Aug. 2, 6 15 p. m.	*24.475	2033.075	7942.450
Guaduas	996	Cloudy	E	24.5	April 2, 1 45 p. m.	3.068	2099.691	7897.241
Santa Ana	998	Clear	E	27.5	Aug. 2, 1 30 p. m.	12.333	2054.479	7933.188
Bogota	2,645	....do	SE	17.0	July 8, 3 00 p. m.	4.994	2103.196	7891.810
Montserrate	3,193	Cloudy	E. SE.	9.0	July 8, 11 30 a. m.	5.215	2098.995	7895.790

* Las quemas and volcanic smoke.

5. SANTA FÉ DE BOGOTA. (Elevation, 2,645 meters.)

(Dry air, per 10,000, per volume.)

Sky.	Wind.	Temperature of air, Celsius.	1850.	Carbonic acid.	Oxygen.	Nitrogen.
		°	*h. m.*			
Clear	SE	18.0	Mar. 7, 11 30 a.m.	3.864	2102.099	7894.037
Cloudy	E	15.5	Apr. 12, 9 45 a.m.	3.664	2100.382	7895.954
Do	E	16.0	May 8, 11 30 a.m.	3.609	2099.032	7897.359
Do	E	16.5	May 9, 9 30 a.m.	3.824	2099.250	7896.926
Do	SE	16.5	June 15, 10 00 a.m.	4.192	2099.516	7896.302
Clear	E. SE	17.5	July 24, 11 25 a.m.	4.249	2101.765	7893.986
Cloudy	SE	17.5	Aug. 19, 11 20 a.m.	5.043	2101.411	7893.546
Clear	E. SE	17.5	Aug. 23, 11 00 a.m.	4.812	2101.826	7893.362
Cloudy	SE	16.5	Sept. 1, 9 15 a.m.	6.178	2102.434	7891.388
Clear	Calm	13.0	Sept. 2, 0 00 a.m.	7.649	2101.710	7890.651
Cloudy	E. SE	12.5	Sept. 2, 3 00 a.m.	16.291	2096.629	7887.080
Do	SE	18.5	Sept. 2, 4 10 p.m.	17.040	2103.011	7879.949
Clear	E. SE	16.5	Sept. 3, 9 00 a.m.	15.853	2101.976	7882.171
Cloudy	SE	19.0	Sept. 3, 4 30 p.m.	48.963	2103.179	7847.858
Do	SE	19.0	Sept. 3, 4 30 p.m.	49.043	2103.197	7847.760
Do	E	18.5	Sept. 4, 3 00 p.m.	13.261	2102.927	7883.812
Do	SE	16.5	Sept. 4, 5 00 p.m.	8.648	2100.355	7890.997
Do	NE	16.5	Sept. 8, 9 30 a.m.	12.829	2102.097	7885.074
Do	E. SE	19.0	Sept. 9, 4 00 p.m.	7.512	2103.082	7889.406
Clear	E. SE	19.5	Sept. 10, 1 10 p.m.	4.583	2103.199	7892.218
Cloudy	SE	17.0	Sept. 12, 10 00 a.m.	4.709	2102.689	7892.602
Do	SE	16.5	Oct. 3, 9 15 a.m.	4.751	2102.377	7892.872

It may be observed with respect to these experiments, that at the beginning of the dry season the trees are cut down for agricultural purposes, so that they may be burned just before the rainy season. These conflagrations (called "*las quemas*") last for several days; they are most extensive during the latter part of August and beginning of September, and take place also to a less extent toward the end of February and beginning of March. Volcanic craters, at a short distance from Bogota, also pour carbonic acid at intervals into the atmosphere. On September 2, 1850, the summit of Montserrat was enveloped in a dark gray vail of vapor; the air was so oppressive that many persons were affected, breathing with difficulty. On September 4 it began to rain, and by the 9th the rainy season had fairly commenced, while "*las quemas*" had ceased in the immediate and remote neighborhood of Bogota. On a former occasion, (Ann. Ch. and de Phys., ser. 3, vol. viii., p. 450,) on November 20, 1842, at Guadelupe, Lewy detected 147.6 parts of carbonic acid in 10,000 volumes of air; and on the 23d of that month 89.0 carbonic acid; while in the dense tropical vegetation of the mangrove thickets upon the river Salee—and due, no doubt, to the decomposition of carbonic acid by the action of an energetic vegetable life—the amount of this gas falls to 2.6. If these results of Lewy be correct, the great excess of carbonic acid in the atmosphere of the locality observed has its origin in volcanic emanations; and Lewy infers from his experiments that its presence is not due to a disappearance of oxygen. The air was collected in exhausted globes, and the analysis was performed by Dumas and Boussingault's process, by which the oxygen is absorbed by copper heated to redness, and the carbonic acid is obtained by absorption by caustic potassa.

The foregoing analyses give a clear view of our knowledge of the atmospheric carbonic acid. Before proceeding to the analysis of the air of inhabited apartments, I will cite an example from the air of badly-ventilated mines, in which, from the earth, from the breath and light of the miners, and from the combustion of gunpowder, the air has become deteriorated. The following results were obtained by Mr. Heywood, (Tomlinson's Rud. Treatise on Warming and Ventilation, p. 256,) from the analysis of 18 samples of air from mines in Cornwall and Devon:

Oxygen (by volume)	17.067
Nitrogen (by volume)	82.848
Carbonic acid	0.085
	100.000

In one instance he found only 14.51 oxygen, and in another as much as 0.23 carbonic acid.

Dr. R. Angus Smith, (Quar. Jour. of Science, April, 1865, p. 222,) in an essay upon the salubrity of mines, gives the following table for the percentage of oxygen in the air resulting from five or six hundred analyses:

Analyses of air varying in the amount of oxygen per cent. by volume.

Northeast seashore and open heath of Scotland	20.999
Tops of hills—Scotland	20.98
Base of hills—Scotland	20.98
Suburb of Manchester in wet weather	20.98
Front street ½ mile from Exchange—(dry)	20.945
Back of house	20.936
Unhealthy parts of Perth, favorable—windy day	20.935
Fog and frost in Manchester	20.91
Sitting room which felt close	20.89
After six hours of a petroleum lamp	20.83
Pit of a theater	20.74
Gallery	20.36
When candles go out, from presence of carbonic acid	18.5
Difficult to remain in, from presence of carbonic acid	17.2

Summary of analyses of air in mines—oxygen.

Average in 339 specimens	20.26
Lowest	18.27
Average in large spaces	20.77
Currents	20.65
Just under shafts	20.424
In ends	20.18
In swamps	20.14
In all other places	20.32

Analyses of atmospheres varying in carbonic acid.

	Average carbonic acid, per 10,000 volumes.
Manchester streets—usual	4.03
During fogs	6.79
About middens	7.74
Average	4.42
Average fogs excepted	4.24
Average fogs and middens excepted	4.08
Where the fields begin	3.69
In close buildings	16.04
Minimum of suburbs	2.91
Over north Scotland, (towns excepted)	3.36
Candle goes out	180 to 250
Lowest found in mines	250.
Lowest entered for experiment	400.
Average of the mines	78.5

III. CARBONIC ACID IN THE AIR OF APARTMENTS.

Leblanc (Jour. Pr. Ch., xxvii, p. 215, and Comptes Rendus, Juin, 1842, p. 862) made an extensive series of analyses of the air of different inhabited apartments of Paris, comprising chambers, lecture-rooms, hospitals, &c. He determined the constituents of the air in most instances by the method of Dumas and Boussingault, but in some cases he ascertained the carbonic acid by Brunner's process. Leblanc's results are given in the original by weight: I have therefore recalculated them for volumes, using for the purpose the specific gravities of Erdmann's and Marchand's tables. I have also added a column of the relative amount of carbonic acid present, assuming four volumes in 10,000 of air as a unit of measure. It will be seen from these analyses (column of numbers 1, 2, and 3) that vegetation in greenhouses diminishes the amount of carbonic acid which is normally in the air: that in an *ordinary* sleeping apartment for two persons the ventilation from accidental causes is superior; that in such *crowded* apartments the carbonic acid is in great excess from insufficient ventilation, which is also the case for lecture-rooms, schools, and dormitories of hospitals.

I would call especial attention to the analyses of the air of the chamber of deputies and of the opera comique, both ventilated artificially with the greatest care, so that we may compare these results with those obtained in the Capitol extension.

Leblanc's results are interesting in respect to the death of animals in artificial atmospheres. Thus a small bird died in a room containing less carbonic acid than existed in the air of the majority of the apartments examined, and a dog survived longer in air containing the enormous amount of 1,991 volumes per 10,000 of carbonic acid than in an atmosphere from burning charcoal in which 301 volumes of this gas were present. The cause of the latter superior deadly effect is attributable to the presence of the very poisonous gas, carbonic oxide, emitted by the charcoal.

Table of Leblanc's analyses of the air of badly ventilated apartments.

No. of analysis.	Air collected from	Oxygen in 10,000 dry air, per volume.	Carbonic acid in 10 000 dry air, per volume.	Relative carbonic acid that of air, 4 volumes per 10 000.	Capacity of room.	No. of individuals.	Hours that the apartment was closed.	Volume air per person while apartment was closed.	Volume air per hour and per person.	Remarks.
					Cu. met.			*Cu. met.*	*Cu. met.*	
1	Buffon's hot house, Jardin des Plantes, (evening)	2081.2	.....	.....	273.7	.....	12	.....	.....	At 6 p. m. tropical plants; insolation two thirds of the day.
2	Buffon's hot house, Jardin des Plantes, (morning)	2076.7	0.65	0.46	.....	.....	24	.....	.....	At 6 p. m., February 10, 1842, 8 a. m., air taken the day following, I.
3	Chemical lecture room, Sorbonne, (before lecture)	2028.8	42.51	10.63	1,000	400	½	.....	.....	Air taken at commencement of M. Dumas's lecture.
4	Chemical lecture room, Sorbonne, (after the lecture)	1986.3	67.36	16.84	.....	900	1½	1.1	0.74	Air taken at close of M. Dumas's lecture.
5	Sleeping apartment	2074.9	2.62	0.65	81	2	8	40.5	50.	Without chimney, air 1 meter above floor.
6	Women's room, Notre Dame du Rosaire	2072.1	5.89	1.47	1,958	54	2¾	36.0	4.0	Air 9 a. m., 2¾ hours after the windows had been open for airing room.
7	Women's room, Nòtre Dame du Rosaire	2055.	18.31	4.58	.....	54	9	.....	4.0	Air 6 a. m., 1½ meter above floor; two stoves, fire all night.
8	Garret dormitory, Salpetrière section of incurable insane.	2036.9	52.32	13.08	611.1	55	8¼	11.1	1.4	Air 0.6 meter above floor; doors and windows closed imperfectly.
9	Dormitory Salpetrière epileptics	2044.1	37.93	9.49	2,417	121	9	19.9	2.2	Doors and windows closed better.
10	Room in asylum, 2d arrondissement	2054.	17.66	4.41	230	116	3	.....	.....	Air 0.6 meter above floor; doors half opened, boys and girls from 3 to 6 years.
11	School room, 2d arrondissement, with full draught	2065.8	Lost.	.....	721	180	4	.....	.....	Air 1¼ meter close floor; 1,080 cubic meters escaped hourly by the chimney; boys from 7 to 10 years of age.
12	School room, 2d arrondissement, imperfect draught	.....	30.74	7.68	.....	.....	4	.....	.....	Air taken 2½ meters above floor, and 837 cubic meters air escaped hourly by the chimney.
13	School-room, 2d arrondissement, imperfectly closed	.....	56.90	14.22	.....	.....	4	3.1	0.77	All openings closed; temperature inside, 18°; temperature outside, 16°; respiration accelerated.
14	Chamber of deputies, inside of the entering air flue	.....	16.35	4.09	5,000	600	2½	.....	.....	11,000 cubic meters air passed through the chimney hourly.
15	Opera comique, parterre	.....	15.04	3.76	.....	1,000	2¾	.....	.....	Air taken 1 meter above floor; 80,000 cubic meters passed through the chimney hourly.
16	Opera comique, ceiling	.....	28.12	7.03	.....	.....	2½	.....	.....	Air taken at ceiling near flue conducting air to chandelier.
17	A close stable in the military school	2012.5	6.87	1.72	339.5	9 horses	7¾	37.7	4.7	Air taken 2 meters above floor.
18	Another stable in the military school with the ventilator open.	2073.1	14.39	3.60	2,980	57 hor's	8	52.2	6.5	Natural draught through a ventilator.

Artificial atmosphere.

Remarks.	Relative carbonic acid compared with air containing 4 volumes per 10,000.	Carbonic acid, per 10,000.		Oxygen, per 10,000.		Nitrogen, per 10,000, per weight.	Carbonic oxide, per 10,000, per weight.	Hydrogen, per 10,000, per weight.
		Weight.	Volume.	Weight.	Volume.			
Suffocating air from burning charcoal*	75.37	461	301.5	1919	1735.7	7562	54	4
Suffocating air from burning charcoal†	5.07	31	20.3	......	......	......	......	......
Suffocating air with pure carbonic acid‡	497.7	3044	1990.7	1600	1447.2	......	......	......

* Air collected ten minutes after the death of a dog placed therein, and on the instant of the extinction of a candle.
† Air deadly for a bullfinch; flame of a candle unchanged.
‡ Air collected at the moment of the death of a dog placed therein.

Raymond de Luna (Jahresbericht, xiii, 107, estudios quimicos sobre el aire atmosferico de Madrid, 1860) has made an investigation, containing the following results of experiments upon the air of Madrid:

Raymond de Luna's analyses.

Locality.	Carbonic acid, per 10,000 volumes of air.	Relative carbonic acid.
Princess' hospital, Madrid	30.00	5.8
General hospital, Madrid	43.00	8.3
Within the walls of the city of Madrid	5.17	1.0
Without the walls of the city of Madrid	4.50	
Air of a bedroom on rising in the morning	48.00	9.2
After ventilating the same for two hours	16.00	3.0

Pettenkoffer, (Abhandlung Bayr. Acad. der Wissenschaften II, pp. 1, 19, 69; also in Jour. Pr. Ch. lxxxv, 165,) in an extensive series of experiments performed according to his method of analysis for determining carbonic acid, obtained the results contained in the following table.

It will be observed that the air of ordinary and not crowded rooms is not deficient in ventilation, which takes place through the *walls* and crevices; (see ex. 12, 13, &c;) that there are differences in degrees for the ventilation of such rooms, and when they have from 5 to 9 per 10,000 per volume of carbonic acid, which is equal to 1.1 –2.0 relative carbonic acid, they are free from any closeness to the senses.

Crowded rooms, lecture and school rooms, provided with no artificial ventilation, have an accumulation of carbonic acid to a dangerous degree.

Experiments 17–20 show the escape of carbonic acid by diffusion through the walls and crevices.

Table of Pettenkoffer's analyses of the air of rooms.

No. of analysis.	Remarks.	Carbonic acid in 10,000 volumes.	Relative carbonic acid, 4.5 = 1.0.
1	External air, Innsbruck, Pettenkoffer's method	4.52	1.0
2	External air, Innsbruck, Gilm's method	4.09	....
3	Air of dwelling-room, Pettenkoffer's method	7.40	1.645
4	Air of dwelling-room, Gilm's method	7.41	....
5	Air of dwelling-room, Pettenkoffer s method	6.11	1.358
6	Air of dwelling-room, Gilm's method	6.33	1.407
7	External air at Munich	4.5	1.0
8	Air from dwelling-room, Munich	6.0	1.333
9	Air from badly ventilated workshop	19.7	4.378
10	Air from very full room 14 feet high—at floor	22.4	4.978
11	Air from very full room 14 feet high—at ceiling	26.6	5.911
12	Air from room free from any closeness	5.0	1.111
13	Air from room free from any closeness	9.0	2.000
14	Air from very full lecture-room	32.0	7.111
15	Air from Munich beer saloon	49.0	10.890
16	Air from a well-filled school-room	72.0	16.000
17	Air from well-closed room, filled with fumes of burning charcoal	141.0	31.340
18	Air from well-closed room an hour later	51.0	11.330
19	Air from well-closed room an hour later	22.0	4.889
20	Air from well-closed room an hour later	*12.0	2.667

* Diffusion through the solid walls and crevices.

Dr. Hammond (Hygiene with reference to the military service) gives the following results of his examination of the air of the army hospitals:

Table of analyses of air of army hospitals.

Remarks.	Carbonic acid, per 10,000 volumes of air.	Relative carbonic acid.
External air	3.7	1.0
Air in the hospitals of best ventilation	6.8	1.8
Air in the hospitals of worst ventilation	21.1	5.7
Air in a bedroom on rising	9.5	2.6
Air of a bedroom after ventilating for three hours	4.3	1.2

Peclet (Nouveaux Documents Relatifs au Chauffage et à la Ventilation, Paris, 1853) gives the following results of experiments by Leblanc upon the condition of, I, a ventilated cell in the prison Mazas; II, of a similar cell not ventilated.

The experiments were performed by the action of a committee comprising Arago, Gay Lussac, Pouillet, Dumas, Boussingault, Andral, Péclet, Leblanc, and others.

In cell No. I a ventilation of six cubic meters of air per hour was insufficient to remove the odor extending into the cell from the siége d'aisance; but ten cubic meters were effectual for the purpose. The experimentor was confined in the cell during ten hours with a candle, which was lighted during 2½ hours after closing the doors. The ventilation No. I was at the rate of 10 cubic meters per hour, except for the first two hours, when it was somewhat less. During the first few hours the experimentor experienced a slight feeling of disgust in consequence of the insufficient ventilation, but this passed away completely.

Table of Leblanc's experiments on the ventilation of the prison Mazas.

Locality.	Carbonic acid, per 10,000 volumes.	Relative carbonic acid. Unity = 5.0 per 10,000.	Relative humidity.	Remarks.
I. A ventilated cell.	21.58	4.32	80	External air relative $h=75.0$
II. Cell not ventilated.	65.40	13.08	....	.

Lassaigne (l'Institut, No. 654, July 15, 1846, p. 240, and Jour. Pr. Ch., xlvi, p. 287) performed some experiments upon the composition of the air in unventilated places which had served for the respiration of men and horses. The determination was effected by absorption by caustic potassa. In the first two experiments the air was taken after a lecture which had lasted two hours; all the crevices of the apartment having been closed as effectually as possible. As may be perceived, the amount of carbonic acid present is enormous, being, as in the case of a cell in the prison Mazas, as much as four times the normal quantity contained in the atmosphere.

Table of Lassaigne's experiments upon unventilated rooms.

Experiment.	Locality.	Capacity, cubic meters.	Individuals present.	Remarks.	Carbonic acid, per 10,000 volumes of air.	Relative carbonic acid. The air of Paris = 5 = 1.00.
1	Lecture-room ceiling.	280	52	No ventilation	62	12.4
1	Lecture-room floor	280	52	......do	55	11.0
2	Lecture-room ceiling.	280	52	......do	49	9.8
2	Lecture-room floor	280	52	......do	43	8.7
3	Stable	78	2 horses	......do	52	10.4
3	Stable	78	2 horses	......do	55	11.0
4	Stable	......	8 horses	Closed exp't after 45′	32	6.4

Loppens (l'Institut, 1845, p. 26) obtained the following results in the air of a theater at Ghent. These experiments, like those of Lassaigne and others, establish the fact that the carbonic acid of an unventilated room is uniformly diffused therein, the slight difference being in favor of the ceiling, and not of the floor, as was formerly ignorantly assumed from the superior specific weight of this gas:

Table of Loppens's experiments on a theater.

Air of the theater at Ghent.	Carbonic acid, per volume, per 10,000.		Relative carbonic acid, that of air = 5 = 1.	
	Minimum.	Maximum.	Minimum.	Maximum.
From the parterre	26.7	46.3	5.3	9.3
From above the galleries	43.9	53.6	8.8	10.7

Roscoe (Qr. Jour. Ch. Soc., x, 251) obtained the following interesting results of an "investigation for the purpose of supplying chemical data respecting the warming

and ventilation of private dwelling-houses, including barracks, under a commission appointed for that purpose by the general board of health" in London. Roscoe assumes that the following are the conditions of the deterioration of air in such localities:

1. The presence of an excessive quantity of carbonic acid or of other gases.
2. Too much or too little moisture.
3. The presence of organic putrescent bodies, the effluvia arising from the decomposition of animal or vegetable matter.
4. Inconvenient elevation of temperature.

Roscoe assumes the proportion of carbonic acid in a room which has served for respiration to be the measure of the deterioration arising from the breath, with respect both to the carbonic acid and to the putrescent matters exhaled.

The following table comprises Roscoe's results. The experiments were performed by aspirating a known volume of air, absorbing the moisture by *sulphuric acid*, and the carbonic acid by *caustic potassa*, both contained in tubes filled with fragments of pumice-stone:

Table of Roscoe's experiments upon ventilation.

Number of experiments.	Locality.	Cubic feet in the inclosed space.	Number of persons present.	Cubic feet per head per hour.	Relative humidity.	Carbonic acid per 10,000 per volume.	Relative carbonic acid.	Deviation from mean.	Remarks.
III	In London, Feb. 27, '57	....	.....	......	65.5	3.7	1.0	....	Windy day.
IV	No. 16, Wellington barracks.	7,920	16	13.3	66.2	12.42	3.4	....	Ventilation shut off.
V	......do	7,920	16	13 0	59.5	11.89	3.2	....	
VI	......do	7,920	16	......	65.0	14.18	3.8	....	
VII	Large day-school for boys.	22,140	164	6	75.0	23.71	6.4	....	Accid'l ventilation.
VIII	Another day-school for boys.	4,640	67	4	74.0	31.9	8.6	....	
IX*a*	Small unventilated family dwelling.	940	9	......	......	12.13	3.3	+0.31	6 in. below ceiling.
IX*b*	......do	940	9	......	......	12.76	3.4	......	2½ ft. above floor.
X*a*	A school-room, same as VIII.	4,640	70	......	......	33.05	8.9	−0.16	6 in. below ceiling.
X*b*	......do	4,640	70	......	......	32.53	8.8	......	3 ft. above floor.
XI*a*	......do	4,640	70	......	......	23.90	6.5	+0.34	6 in. below ceiling.
XI*b*	......do	4,640	70	......	......	24.59	6.6	......	2½ ft. above floor.
XII*a*	The same as VII	22,140	160	......	......	26.96	7.3	+1.26	6 in. below ceiling.
XII*b*	......do	22,140	160	......	......	29.49	8.0	......	3 ft. above floor.
XIII*a*	The same as IV	7,920	20	......	......	13.82	3.7	+2.87	Arnold's ventilation. *a* 3 in. below ceiling.
XIII*b*	......do	7,920	20	......	......	16.84	4.6	......	*b* 2½ ft. above floor.
XIV*a*	Theater	(*)	(†)	......	......	26.37	7.1	....	4 ft. above parterre.
XIV*b*	......do	(*)	(†)	......	......	32.12	8.7	....	34 ft. above parterre, opposite gallery.

* Not determined. † Moderately full.

Roscoe also performed experiments upon the escape of carbonic acid through the crevices of a room, and by diffusion through its walls. The results accord with those obtained independently by Pettenkoffer, and demonstrate that a large amount of carbonic acid escapes from an unventilated room in this way. In experiment I, carbonic acid was evolved in a room containing two persons. The flue was closed and was without fire. All the doors (four) and windows (two) were shut. The capacity of the room was 2,560 cubic feet. The following are the results:

Experiment I.

Carbonic acid determined at consecutive half hours gave—	At 0h. 0m.	At 0h. 30m.	At 1h. 0m.	At 1h. 30m.
Volume of carbonic acid per 10,000 volumes of air	72.07	33.10	30.99	30.99

It is thus seen that the carbonic acid diminishes in half an hour from 0.7 to 0.3 per cent. of the total volume of air, although the direct ventilation was checked. Roscoe supposes that the permanency of 3 per cent. carbonic acid after the first half hour is due to the respiration of the two persons in the confined atmosphere.

Experiment II was instituted for the pupose of ascertaining the diffusion of carbonic acid through brick and mortar walls. For this purpose a brick was cemented with pitch into the end of a box lined with pitch, and of the dimensions 3 feet by 9 inches by 4½ inches. Carbonic acid was led into the box by two tubes cemented into the sides. After the box had stood for sufficient time to permit a uniform mixture of the gases, samples were taken in consecutive hours, collected in a tube over mercury, and the proportion of carbonic acid in the air determined. In order to control errors arising from a leakage of the box, another experiment was performed, in which the whole brick was covered with pitch and the leakage thus determined.

Experiment II.

Carbonic acid determined at consecutive hours.	At 0h.	At 1h.	At 2h.	LOSS OF CARBONIC ACID BY DIFFERENCE IN PER CENTS.		
	1.	2.	3.	In 1st hour.	In 2d hour.	Total in 2 hours.
Samples	16.96	14.22	12.17	2.74	2.05	4.79

The experiment with a brick pitched all over showed a loss by leakage in two hours of 1.54 per cent. of carbonic acid. Hence the amount of carbonic acid which diffused through the naked brick in two hours = 4.79 — 1.54 = 3.25, or a total of 16 per cent. of carbonic acid. In other words, when an inclosed space contained 16 per cent. of carbonic acid, three and a quarter per cent. escaped through a solid brick in two hours.

II.—ANALYSES AND OBSERVATIONS AT THE CAPITOL.

GENERAL DATA AND RESULTS.

The following table comprises the data obtained and the results which have been deduced from my experiments upon the ventilation of the Capitol extension. The first and second columns contain the places of observation and the consecutive order of experiments, and columns 3 and 4 their dates and hours. Columns 5, 6, 7, 12, and 13 give the data for calculating the volume of carbonic acid contained in 10,000 volumes of air. These data are not given for the experiments of June 30, 1864, on account of the imperfection of the apparatus employed at that date. I regard these experiments as approximately correct, but without the confidence attaching to those performed in the present year. Columns 9 and 10 contain the data for computing 11, the relative humidities of the air, in which 100 is taken as the point of saturation with moisture of air of the respective temperatures. The inferences to be drawn from the experiments upon moisture are deferred to a subsequent page.

Let us consider, in the present connection, columns 14, 15, and 16, which concern the proportion found for the carbonic acid of the air in the apartments in question, and a comparison of the quantity of this gas with that already existing in the external atmosphere.

Table of data and results of the determination of the carbonic acid and relative humidity of the air in connection with the ventilation of the Capitol extension.

WETHERILL.

No. of analysis.	Place of observation.	Date.	Time.	Quantity of air taken.	Temperature of air vessel, C°.	Barometer, millimeters, at 0° C.	Temperature of air, Fahr.	Temp. of air, C°. Wet bulb.	Temp. of air, C°. Dry bulb.	Relative humidity.	C. C. of oxalic solution. Before carb. acid.	C. C. of oxalic solution. After carb. acid.	Carb. acid per 10,000 per vol. Experiments.	Carb. acid per 10,000 per vol. Mean.	Relative carbonic acid.	Remarks.
		1864.	*h. m.*				°	°								
1	Smithsonian laboratory	June 27	M	....	...	762.6	90.5	24	32.5	47	....	....	....	....	....	After very dry spell, with breeze from the north, and storm approaching.
2	Capitol, northeast portico	June 27	2.00 p. m	....	....	759.9	86.9	23	30.5	51	....	....	....	....	....	
3	Senate, southeast corner, over ventilator.	June 27	2.15 p. m	....	....	759.4	86	22.5	30	50	....	....	....	....	....	Storm began.
4	Senate, opposite chair	June 27	2.30 p. m	...	...	759.4	82.4	25	28	77	....	....	....	....	....	Hard rain: wind blowing in the doors.
5	Senate, ladies' gallery, southeast corner.	June 27	2.45 p. m	...	...	759.4	84.2	23	29	58	....	....	....	....	....	Storm ceasing.
6	Senate, Sergeant-at-arms' office	June 28	11.50 a. m	....	.....	769.3	74.3	15	23.5	35	....	....	....	....	....	
7	Senate, southeast corner, over ventilator.	June 28	M.	...		769.3	77	16	25	34	....	....	....	....	....	
8	Senate, opposite chair	June 28	12.15 p. m	...	..	769.3	77	16	25	31	....	....	....	....	....	
9	Senate, ladies' gallery, southeast corner.	June 28	12.45 p. m	...	...	769.3	77.9	16	25.5	32	....	....	....	....	....	
10	Smithsonian laboratory	June 28	2.00 p. m	...	...	770.9	77.9	16	25.5	32	....	....	....	....	....	
11	Smithsonian laboratory	June 29	4.00 p. m	...	...	774.6	78.8	16	26	30	....	....	....	....	....	
12	Senate, southeast corner ventilator.	June 29	4.35 p. m	....	.....	774.5	77.9	16.5	25.5	34	....	....	....	....	....	
13	Senate, opposite chair	June 29	4.35 p. m	...	...	774.5	78.8	17	26	36	....	....	....	....	....	Galleries nearly empty.
14	Senate, ladies' gallery, southeast corner.	June 29	4.45 p. m	...	....	774.5	78.8	17	26	36	....	....	....	....	....	
15	Capitol, northeast portico	June 29	4.45 p. m	...	..	774.5	78.8	16	26	30	....	....	....	....	....	
16	Smithsonian laboratory	June 30	10.45 a. m	...	.....	765.9	77.0	19	25	54	....	....	3.345	....	....	Breeze: storm approaching.
17	Capitol, main portico	June 30	2.05 p. m	...	.....	763.4	78.8	19	26	48	....	....	3.172	3.258	1	
18	Capitol, main portico, second experiment.	June 30	2.05 p. m	...	..	763.4	78.8	19	26	48	....	....				
19	House of Representatives,* northwest corner.	June 30	2.20 p. m	...	....	762.9	78.8	21	26	62	....	....	6.793	....	....	Storm begun.
20	House of Representatives, second experiment.	June 30	2.20 p. m	....	......	762.9	78.8	21	26	62	....	....	4.185	5.489	1.7	*Capacity House of Representatives, 465,372 cub. ft.
21	House gallery, behind clock	June 30	2.45 p. m	....	....	762.9	78.8	21	26	62	....	....	4.902	....	....	Raining gently.
22	House gallery, second experiment	June 30	2.45 p. m	...	....	762.9	78.8	21	26	62	....	....	4.147	4.525	1.4	The values for carbonic acid are approximate.

Table of data and results of the determination of the carbonic acid and relative humidity of the air, &c.—Continued.

No. of analysis.	Place of observation.	Date.	Time.	Quantity of air taken.	Temperature of air vessel, C°.	Barometer, millimeters, at 0° C.	Temperature of air, Fahr.°	Temp. of air, C°.		Relative humidity.	C. C. of oxalic solution.		Carb. acid per 10,000 per vol.		Relative carbonic acid.	Remarks.
								Wet-bulb.	Dry-bulb.		Before carb. acid.	After carb. acid.	Experiments.	Mean.		
		1864.	*h. m.*													
23	Smithsonian laboratory	July 2	1.15 p. m			759.8	88.2	23.7	31.2	51						Before a storm.
24	Smithsonian laboratory	July 2	2.00 p. m			760.7	78.8	23.5	26	80						After the storm.
25	Capitol, northeast portico	July 2	3.00 p. m			760.7	84.2	25	29	71						
26	Senate,* over southeast corner ventilator.	July 2	3.15 p. m			760.7	82.4	24.5	28	74						Very pleasant air in the Senate after the storm.
27	Senate, six feet from ventilator	July 2	3.20 p. m			760.7	84.2	25	29	71						
28	Senate, opposite chair	July 2	3.25 p. m			760.7	84.2	25	29	71						
29	Senate, over opposite ventilator	July 2	3.28 p. m			760.7	82.4	24.5	28	71						
30	Senate, six feet from ventilator	July 2	3.30 p. m			760.7	84.2	25	29	71						
31	Senate, northwest corner	July 2	3.40 p. m			760.7	84.6	25	29.2	71						
32	Senate, over side ventilator	July 2	3.50 p. m			760.7	82.4	24.5	28	74						
33	Senate, ladies' gallery, southeast corner.	July 2	4.00 p. m			760.7	84.2	24.5	29	68						
34	Senate, stairs to gallery, opposite ventilator.	July 2	4.25 p. m			760.7	80.6	23.5	27	74						
		1865.														
35	Senate, post office near a closed window.	Jan. 24	12.15 p. m			Not taken	61.9	11	16.6	46						Fair weather.
36	Senate, post office, on mantelpiece	Jan. 24	12.15 p. m			do	70.2	12.8	21.2	32						
37	Senate, post office, on mantelpiece	Jan. 24	12.30 p. m			do	70.9	13	21.6	31						
38	Senate, post office, on mantelpiece	Jan. 24	1.55 p. m			do	70.5	13.1	21.4	33						
39	Senate, ladies' gallery, near reporters' gallery.	Jan. 24	2.15 p. m			do	72.0	12.8	22.2	27						
40	Senate, ladies' gallery, near diplomatic gallery.	Jan. 24	2.40 p. m			do	72.3	13	22.4	27						Fire at Smithsonian Institution interrupted the experiment.
41	Senate, air entering fan	Jan. 24	3.00 p. m			do	29.8	— 3.8	— 1.2	56						
42	Senate external air north portico	Jan. 24	12.45 p. m			do	31.3	— 2.8	— 0.4	58						
43	Smithsonian Institution, external air	Feb. 8	10.30 a. m	A	4	753.3	33.8	— 1	1	65	37.5	34.6	2.722			Clear, with gentle breeze
44	Smithsonian Institution, external air	Feb. 8	10.30 a. m	B	4	753.3	33.8	— 1	1	65	37.5	34.8	2.685			
45	Smithsonian Institution, external air	Feb. 8	10.30 a. m	C	4	753.3	33.8	— 1	1	65	37.5	34.7	2.719	2.709	1	
46	Senate, air entering fan	Feb. 9	2.30 p. m	A	4	759.0	30.6	— 3	— 0.6	55	37.5	34.6	2.700			Clouded and windy.
47	Senate, air entering fan, second experiment.	Feb. 9	2.30 p. m	B	3.5	759.0	30.6	— 3	— 0.6	55	37.5	34.8	2.659			
48	Senate, air entering fan third experiment	Feb. 9	2.30 p. m	C	2.5	759.0	30.6	— 3	— 0.6	55	37.5	34.8	2.587	2.649	1	

49	Senate level desks, southeast corner	Feb.	9	3.30 p. m	*a*	20	757.7	70.9	11.4	21.6	20	37.5	35.0	5.491			Fan forty-five revolutions per minute.
50	Senate, level desks, second experiment.	Feb.	9	3.30 p. m	*b*	20	757.7	70.9	11.4	21.6	20	37.5	35.2	5.979	5.735	2.2	
51	Senate, diplomatic gallery	Feb.	9	4.00 p. m.	*c*	20	756.5	68	11.8	22.0	21	37.5	36.0	3.871	......	....	Galleries not full.
52	Senate, diplomatic gallery, second experiment.	Feb.	9	4.00 p. m.	*d*	20	756.5	68	11.8	22.0	21	37.5	35.8	4.085	3.978	1.5	
53	Senate, illuminating loft, northwest corner, over ventilator.	Feb.	9	4.30 p. m.	*e*	20	756.1	64	9.8	17.8	27	37.5	35.5	4.733	......	.....	
54	Senate, illuminating loft, northwest corner, over ventilator, second experiment.	Feb.	9	4.30 p. m.	*f*	20	756.1	64	9.8	17.8	27	37.5	35.7	4.443	4.588	1.7	
55	Smithsonian Institution, dining-room of the Secretary.	Feb.	15	2.10 p. m	*g*	21	758.7	69.8	14.4	21	44	37.5	35.8	4.340	.....	1.6	Rain. Relative humidity, with open windows, =69.
56	House of Representatives, air entering fan.	Feb.	16	3.30 p. m	A	5	753.0	35.2	1.7	1.8	100	37.5	34.7	2.637	....	.....	Raining; fine mist.
57	House of Representatives, air entering fan, second experiment.	Feb.	16	3.30 p. m	B	4	753	35.2	1.7	1.8	100	37.5	34.7	2.785	2.711	1	Galleries not full.
58	House of Representatives, level of desks, northwest corner.	Feb.	16	3.40 p. m	*a*	23	753.4	72.7	14.4	22.6	46½	37.5	35.6	3.495	......	....	Average audience.
59	House of Representatives, level of desks, northwest corner, second experiment.	Feb.	16	3.40 p. m	*b*	23	753.4	72.7	14.4	22.6	46½	37.5	35.8	3.608	3.552	1.3	Fan forty-five revolutions per minute.
60	House of Representatives, diplomatic gallery.	Feb.	16	4.00 p. m	*c*	22	753.4	70.9	13.6	21.6	46½	37.5	36.0	3.913	......	....	
61	House of Representatives, diplomatic gallery, second experiment.	Feb.	16	4.00 p. m	*d*	22	753.4	70.9	13.6	21.6	46½	37.5	36.2	3.157	3.535	1.3	
62	House of Representatives, illuminating loft, northeast corner.	Feb.	16	4.30 p. m	*e*	22	751.4	68.4	12.8	22	48	37.5	35.8	4.065	......	....	
63	House of Representatives, illuminating loft, second experiment.	Feb.	16	4.30 p. m	*f*	22	751.4	68.4	12.8	22	48	37.5	36.0	3.751	3.908	1.4	
64	Dwelling, 311 F street, bedroom second story, front.	Feb.	17	5.15 p. m	*a*	20	753.3	65.2	13.2	18.4	57	37.2	36.0	2.650	......	1	Relative humidity of external air=70.
65	Dwelling, 311 F street, bedroom, second story, front.	Feb.	18	8.00 a. m	*b*	20	759.2	68.4	14.0	20.2	46	37.2	35.2	5.189	.. ..	2.0	Relative humidity of the external air=80.
66	Senate, air entering fan	Feb.	24	10.00 p. m	A	5	771.6	37.4	0.6	3.0	67	37.9	35.2	2.360	....	....	Fan making forty-five revolutions per minute.
67	Senate, air entering fan, second experiment.	Feb.	24	10.00 p.m.	B	5	771.6	37.4	0.6	3.0	67	37.9	35.0	2.825	......	.....	
68	Senate, air entering fan, third experiment.	Feb.	24	10.00 p. m	C	5	771.6	37.4	0.6	3.0	67	37.9	35.0	2.758	2.648	1	Clear weather, and cold.
69	Senate, level of desks, southeast corner.	Feb.	24	8.30 p. m	*a*	17	770.5	66.9	11.4	19.4	31	37.9	35.9	4.275	....	.....	
70	Senate, level of desks, second experiment	Feb.	24	....	*b*	19	770.5	66.9	11.4	19.4	31	37.9	36.0	4.839	4.557	1.7	
71	Senate, reporters' gallery	Feb.	24	9.00 p. m	*c*	20	770.5	70.9	12.6	21.6	28	37.9	36.0	4.814	......	1.8	Galleries crowded.
72	Senate, illuminating loft, near ventilator.	Feb.	24	9.30 p. m	*e*	23	768.9	72.3	13.2	22.4	28½	37.9	34.8	7.269	....	....	Effect of gas-burners in the illuminating loft.
73	Senate, illuminating loft, near ventilator, second experiment.	Feb.	24	9.30 p. m.	*f*	23	768.9	72.3	13.2	22.4	28½	37.9	34.9	7.355	7.312	2.8	

Table of data and results of the determination of the carbonic acid and relative humidity of the air, &c.—Continued.

No. of analysis.	Place of observation.	Date.	Time.	Quantity of air taken.	Temperature of air vessel, C°.	Barometer, millimeters, at 0° C.	Temperature of air, Fahr.°	Temp. of air, C°.		Relative humidity.	C. C. of oxalic solution.		Carb. acid per 10,000 per vol.		Relative carbonic acid.	Remarks.
								Wet-bulb.	Dry-bulb.		Before carb. acid.	After carb. acid	Experiments.	Mean.		
		1865.	h. m.		°		°	°	°							
74	House of Representatives, air entering fan.	Feb. 25	3.30 p.m	...	.....	Not taken	36.7	2.2	2.6	93	.....	.....	.....	.....	.....	Fan thirty revolutions per minute; fine drizzling rain; air passing over 60 square feet of water heated and placed in the air-duct.
75	House of Representatives, southwest corner, outer circle of desks.	Feb. 25	4.00 p.m	...	.....	do	69.4	14	20.8	43	.....	.....	.....	.....	.....	
76	House of Representatives, center circle of desks.	Feb. 25	4.00 p.m	...	.....	do	69.4	14	20.8	43	.....	.....	.....	.....	.....	
77	House of Representatives, Hon. Mr. Baily's desk.	Feb. 25	4.30 p.m	...	.....	do	69.8	14	21	41	.....	.....	.....	.....	.....	
78	House of Representatives, southeast corner, outer circle of desks.	Feb. 25	4.30 p.m	...	.....	do	69.8	14	21	41	.....	.....	.....	.....	.....	
79	House of Representatives, air entering fan.	Feb. 27	3.35 p.m	...	.....	do	51.4	6.6	10.8	49	.....	.....	.....	.....	.....	Very fine day; air passing over the above surface of water, which is not heated.
80	House of Representatives, southwest corner, (as above.)	Feb. 27	3.40 p.m	...	.....	do	71.6	14.2	22	37	.....	.....	.....	.....	.....	
81	House of Representatives, center, (as above.)	Feb. 27	3.40 p.m	...	.....	do	71.6	14	22	35	.....	.....	.....	.....	.....	
82	House of Representatives, Hon. Mr. Baily's desk.	Feb. 27	3.40 p.m	...	.....	do	71.6	14	22	35	.....	.....	.....	.....	.....	
83	House of Representatives, southeast corner, (as above.)	Feb. 27	3.40 p.m	...	.....	do	71.6	14	22	35	.....	.....	.....	.....	.....	
84	Dome, top of balustrade of tholus.	Mar.	2.[illegible]0 p.m	A	23.2	760	64.2	10.7	17.9	34	37.2	34.4	2.801	.....	.....	Wind from southeast, from which quarter the air was taken; weather fine, but atmosphere hazy; 219 feet 2½ inches below upper station.
85	Dome, top of balustrade, second experiment.	Mar.	2.15 p.m	B	23.6	760	64.2	10.7	17.9	34	37.2	34.5	2.901	2.851	1.06	
86	Capitol, first platform steps, main east portico, 4 feet 1½ inches above ground.	Mar.	2.40 p.m	C	21.6	756.5	65	11.1	18.3	35	37.2	34.6	2.686	...	1.00	
87	Secondary public school, Miss Mills	Mar. 31	1.30 p.m	a	19.2	745.8	68	15.6	20	60	37.6	33.4	9.342		3.48	Rainy day; three schools for girls, 6 to 15 years, in one room, corner Pennsylvania avenue and Nineteenth street; air taken in the center of each school at level of desks; attendance, 139 girls and 3 teachers.
88	Primary public school, Miss Robinson.	Mar. 31	1.45 p.m	b	20.4	745.8	68	15.6	20	60	37.6	33.6	10.574	..	3.94	
89	Primary public school, Miss Hubbard.	Mar. 31	1.50 p.m	c	21	745.8	68	15.6	20	60	37.6	34	9.451	..	3.52	

90	Public school, male intermediate first division, Mrs. Rodier, air from teacher's desk	Mar. 31	2.15 p. m	*d*	22.2	745.8	74	18.9	23.3	63	37.6	30.6	17.184		6.40	Twentieth street, near I. 46 boys, from 8 to 15 years, with teachers. Relative humidity of external air 72°, temperature 59°. Carbonic acid 2.686 : 1.
91	Public school, air from north side of room.	Mar. 31	2.20 p. m	*e*	22.8	745.8	75	18.9	23.9	60	37.6	32.3	12.803	..	4.77	
92	Public school, air from south side of room.	Mar. 31	2.30 p. m	*f*	24	745.8	75	16.7	23.9	11	37.6	32.6	12.680	.	4.72	

A discussion of the inferences to be drawn from the results of the experiments upon carbonic acid embraced in the preceding table will be facilitated by considering them in the following groups:

1. OF THE EXTERNAL AIR.

The close agreement between two analyses of the same air, performed simultaneously, demonstrates the accuracy of the results, and repays the labor incurred in the careful preparation of the tests and apparatus employed in the investigation. Collecting the means of all of the analyses of the external air, we have the following group:

Carbonic acid per volume in 10,000 of external air. Mean results.

	Carbonic acid.
1864—June 30	3.258
1865—February 8	2.709
1865—February 9	2.649
1865—February 16	2.711
1865—February 24	2 648
1865—March 28	2.686
Mean from February 8	2.68
Difference from mean	0.031

From which it is seen that the mean volume of carbonic acid per 10,000 at Washington, in the winter, was 2.68, and in the summer, on June 30, 3.26. While not desiring to assign to the analysis of June 30 too great weight, it may be remarked that it was performed upon air collected during a breeze, immediately before a storm, and that it has been shown that under such circumstances the lower strata of air are enriched by the larger proportion of carbonic acid contained in the upper regions.

The small amount of carbonic acid obtained by the analyses is remarkable. The care bestowed upon the experiments and the accordance of the results precludes the supposition of error. If an error exists, it must be always present, and varying in an exact proportion to the carbonic acid; but the method of analysis has been tested by Pettenkoffer and Gilm in a series of comparative experiments with satisfactory results.

The following summary shows the proportion of carbonic acid in the atmosphere obtained by other observers:

Carbonic acid in the atmosphere, per volume, per 10,000.

Observer.	Carbonic acid.	Remarks.
De Saussure	5.74	Maximum } of 104 analyses.
Do	3.15	Minimum } of 104 analyses.
Do	4.15	Mean } of 104 analyses.
Gilm	4.6	Maximum } of 19 analyses.
Do	3.8	Minimum } of 19 analyses.
Do	4.15	Mean } of 19 analyses.
R. Angus Smith	2.2	Hills near Preston.
Do	3.0	At Blackpool.
Marchand	3.1	Mean of 104 analyses.
Mène	2.3 (?)	Mean of 12 analyses.

Four ten-thousandths is the mean proportion of carbonic acid in the atmosphere accepted universally for all seasons and other conditions. From this average there are variations for different conditions. Whether the small amount found for Washington be due to the locality, or be general in the United States, (as is most probable,) I cannot determine, not having been able to discover records of any analyses bearing upon the question. It is probable that Europe, from the greater density of its population, and from the comparative poverty in forest, contains a larger proportion of carbonic acid in the atmosphere than does our country. A research on this subject is much needed. The experiments of Lewy, in South America, throw no light upon the matter, as they exhibit great and sudden changes in the carbonic acid of the air, due to

volcanic action. In the dense tropical vegetation of that country, Lewy found in the groves a considerable diminution of carbonic acid.

Le Blanc also found in the air of the hot-houses of the Jardin des Plantes from 0.0 to 0.6 carbonic acid per 10,000 of air.

2. AIR OF THE HALLS OF CONGRESS.

The mean results of the several analyses may be regarded as very correct. The agreement of the numbers obtained in the analysis of two specimens of the same air is very close—more so, indeed, than was expected from the presence in the neighborhood of the apparatus of persons who took naturally a great interest in the proceedings, and whose movements would tend to the production of currents which might influence the results of the analysis.

The experiments were performed upon air collected at different points and elevations. The air on the floor was compared with that in the galleries, and with that escaping from the ventilators in the illuminating loft.

The experiments were performed in the winter and in the summer, by day and at night, and with various conditions of heat, moisture, storms, barometer, number of individuals present, &c. The following small table gives the mean results:

Table of means of carbonic acid, per 10,000 volumes.

In the legislative halls.	Floor.	Galleries.	Illuminating loft.	Mean.
House of Representatives, June 30, 1864.—Fair audience; storm	5.5	4.5	.....	5.0
Senate, February 9, 1865.—Fair audience; clouds and wind	5.7	4.0	4.6	4.8
House of Representatives, February 16, 1865.—Small audience, rain	3.5	3.5	3.9	3.6
Senate, February 24, night.—Galleries crowded; cold and clear	4.6	4.8	*7.3	4.7
Mean of all of the experiments on the halls	.....	.....	.....	4.5

* Not included in the mean; is due to the gas-lights, 1,530 flames, burning above the ceiling

These results are wonderful, and *demonstrate a very superior ventilation, or renewal of the air.* They show less carbonic acid than was obtained by observers in Europe in the analysis of the external atmosphere, and if carbonic acid be a potent cause of insalubrity in unventilated rooms, our legislators breathe an air more free from this gas than the atmosphere of the Alps. (See page 37 of this report.) This is due to the rapid exchange of the air, and to the small amount of carbonic acid contained therein.

It will be perceived from the experiments that this gas is very uniformly diffused throughout the halls, showing a regular and equable ventilation.

With a uniform velocity of the fan, the carbonic acid of the experiments is inversely proportional to the size of the audience: but from the large volume of air delivered the difference is not very great.

In the experiments in the Senate chamber at night, February 24, I have noted the revolutions at forty-five per minute, as I measured them at 10 p. m.; but the engineer assured me that the fan had been making fifty revolutions per minute during the whole of the evening.

It follows from these observations that the ventilation is as good at night with a crowded hall as in the day-time, but that the velocity of the fan must be attended to to obtain sufficient renewal of the air.

The night experiments demonstrate that while carbonic acid accumulates to a certain extent in the illuminating loft—a phenomenon due to the immense combustion of gas—it has no perceptible effect upon the ventilation. The excess is carried off by the current more rapidly than it can diffuse itself into the hall.

If we now compare the proportion of carbonic acid in our legislative halls with that obtained by observers for other similar places, we shall find an extreme excellence in favor of the ventilation of the Capitol extension. To effect this comparison, I have made an extensive search into the English, German, French, and American scientific journals, and have been surprised to find how little has been done with so interesting a subject.

To enable a fair comparison, I have embodied in the following tables the *relative amount* of carbonic acid in the air of the halls and other apartments—that is, the actual

quantity of carbonic acid obtained divided by the normal amount of the same gas in the external atmosphere:

Tables of the relative amount of carbonic acid.

1. IN HALLS AND LARGE APARTMENTS.

Observer.	Locality.	Relative carb. acid
Wetherill	House of Representatives, Washington, June 30, 1864	.7
Do	...do...do	1.4
Do	Senate, Washington, February 9, 1865	2.2
Do	...do...do	1.5
Do	...do...do	1.7
Do	House of Representatives, Washington, February 16, 1865	1.3
Do	...do...do	1.3
Do	...do...do	1.4
Do	Senate, Washington, February 24, 1865	1.7
Do	...do...do	1.8
	Mean of the above	1.6
Leblanc	Lecture-room, Sorbonne, Paris, before the lecture	10.6
Do	Lecture-room, Sorbonne, Paris, after the lecture	16.8
Do	Chamber of Deputies of France	4.0
Do	Opera comique, parterre	3.8
Do	Opera comique, ceiling	7.0
Pettenkoffer	A lecture-room	7.1
Laissaigne	A lecture-room, ceiling	12.4
Do	A lecture-room, floor	11.0
Do	A lecture-room, ceiling	9.8
Do	A lecture-room, floor	8.7
Loppens	A theater, parterre	9.3
Do	A theater, gallery	10.7
Roscoe	A theater, parterre	7.1
Do	A theater, gallery	8.7
R. Angus Smith	A theater, pit, late in the evening	6.3 to 8.0

Tables of the relative amount of carbonic acid—Continued.

2. IN SCHOOLS.

Observer.	Locality.	Relative carb. acid.
Wetherill	A public school in Washington	3.5
Do	Same, in another part of the room	3.9
Do	...do...do	3.5
Do	A public school in Washington, Mrs. Rodier's school; mean of three analyses in different parts of room.	5.3
Leblanc	Schools in Paris	7.7
Do	...do	14.2
Pettenkoffer	A school in Germany, (well filled)	16.0
Roscoe	Schools in England	6.4
Do	...do	8.4
Do	...do	8.8
Do	...do	6.6
Do	...do	8.0

3. IN DWELLING-ROOMS.

Wetherill	Dining-room, occupied by ladies sewing, in Washington	1.6
Do	A sleeping-room immediately after rising, in Washington	2.0
Leblanc	A sleeping apartment in Paris	0.7
Do	A sleeping apartment in a convent, 54 persons	1.5
Do	do do	4.6
Do	A sleeping apartment in a hospital, 55 persons	13.1
Do	A sleeping apartment in a hospital, 121 persons	9.5
Do	A sleeping apartment in an asylum, 116 persons	4.4
Roscoe	Military barracks, mean of experiments, England	3.7
Do	Unventilated family dwelling	3.4
Pettenkoffer and Gilm., mean	A dwelling-room	1.6
Do	do	1.4
Pettenkoffer	A dwelling-room	1.3
Do	A very full room, floor	5.0
Do	A very full room, ceiling	5.9
Do	A room free from any closeness	1.1
Do	do	2.0

4. IN MISCELLANEOUS APARTMENTS.

Pettenkoffer	A badly ventilated work-shop, Germany	4.4
Do	A Munich beer saloon	10.9
Leblanc	Mazas prison, France, a cell well ventilated	4.3
Do	do do	13.1
R. Angus Smith	Mines of Cornwall, mean of 300 experiments	19.5
Do	Mines of Cornwall, maximum	56.5
Raymond de Luna	Hospital, Madrid	5.8
Do	do	8.3
Do	Air of bedroom, on rising	9.2
Do	Air of bedroom, after two hours' ventilation	3.0
Hammond	Hospitals, United States, best ventilation	1.8
Do	do do	5.7
Do	Air of bedroom, on rising	2.6
Do	Air of bedroom, after three hours' ventilation	1.2

A consideration of these tables will show that the ventilation of the halls of Congress is far superior to the ventilation of the French Chamber of Deputies, or of any other large, well-filled apartment in Europe upon which experiments have been recorded, and is the same as that of our airy and well-ventilated private dwellings. In the latter, according to Pettenkoffer's experiments, with which my own accord, a room having in its air a relative carbonic acid of 2.0—that is, twice as much as exists in the external and normal air—is free from any closeness. The ventilation of the halls of legislation falls within this limit.

Experiments 64 and 65, in the table of data and results, were performed upon the air of my own sleeping apartment, which is a fine, large room of 5,700 cubic feet capacity, and remarkably free from closeness. Doors (three) and windows (two) were situated in three of the sides of the room, and upon the fourth was an anthracite coal fire in a grate. When the air of experiment 64 was taken, the room had been aired, and was unoccupied, and the result demonstrated a relative amount of carbonic acid = 1; that is, of equal purity with the external air. Several persons occupied the room in the evening, and two adults and two small children slept in it. The air of experiment 65 was taken the next morning, immediately upon rising, and yielded a relative carbonic acid = 2, showing thus that a good ventilation had been effected by the action of the fire in the grate. General Morin (Expériences sur les effets de ventilation produits par les cheminées d'appartement. Comptes Rendus, lvi, p. 16, 1853) performed experiments upon the ventilating effect of chimneys and the crevices of doors, windows, &c., upon an office in the Conservatoire des Arts et Métiers. The room could be heated at pleasure by an open fire or by the register of a hot-air furnace. It was occupied usually by a single person, although from ten to twelve assembled there occasionally for a few moments. Under these circumstances the room was sufficiently ventilated by the sole action of the chimney, without fire. The quantity of air evacuated by the chimney was determined from its velocity, which was measured, first, for the action of the hot air furnace alone, and, second, for a fire in the chimney. He experimented also with fires of wood, coal, and illuminating gas.

When the external air had the temperature of from 35.24° to 50° Fahrenheit, and

the interior temperature ranged from 64.4° to 71.6°, the chimney withdrew from the room 400 cubic meters per hour, which is equal to 235½ cubic feet per minute.

The furnace introduced 154 cubic meters of hot air of temperature between 127° and 212° Fahrenheit, consequently 246 cubic meters per hour, equal to 144.8 cubic feet per minute, entered the apartment by the crevices of the doors and windows; from which it appears that an abundant ventilation was effected by the action of the chimney.

The dwellings of citizens in the ordinary circles of life are generally well ventilated for the number of persons usually within them. This ventilation is effected, by the usual construction of houses, through accidental sources; that is, the ventilation was not kept in view in the plan. Experience has shown it to be sufficient in most of these cases, and hence the general attention has been diverted from the importance of ventilating larger and more crowded rooms in which persons are detained for a comparatively short time.

It would prove satisfactory if the ventilation of public halls approached the condition of the ordinary houses of our more affluent citizens; but in general they vie with the crowded and small habitations of the poor in an impure atmosphere. The experiments performed have shown that the halls of Congress are free from this defect, and that they possess a superior ventilation. The fault which some have found with them arises, as will be shown directly, from a deficiency not of *air*, but of *moisture*.

The public schools of Washington, of which the air was examined, were not situated in buildings constructed for the purpose. They are not as deficient in ventilation as the schools of France, England, and Germany, on which we have experiments; but are yet too much so to secure that important desideratum in the education of the young, "a sound mind in a sound body." It is understood that these school-rooms are merely temporary, and it is to be hoped that no delay will occur in the change of their pupils to rooms more conducive to health.

Air from the top of the dome.—It having been supposed by some that the introduction of fresh air from a great elevation would secure a purer atmosphere for the purposes of ventilation, I performed experiments (84, 85, 86) upon the external air taken from the top of the dome, comparing it with that received near the level of the ground, upon the first platform of the steps ascending the main portico of the Capitol. De Saussure, Gay Lussac, Schlagintweit, and others obtained a *larger proportion of carbonic acid* in the superior strata of the atmosphere; my results confirmed this fact for the difference of level between the ground and summit of the dome. Placing the proportion of carbonic acid in the former at 1, the relative carbonic acid at the summit of the dome = 1.05. The wind was from the southeast, and consequently not from the densely peopled portion of the city. Probably an air coming from the city would have been found still richer in carbonic acid, which had proceeded from the chimneys of the dwellings and manufactories. Hence it was shown to be undesirable, as concerns the carbonic acid, to receive the air from too great an elevation.

III. THE QUANTITY OF FRESH AIR INTRODUCED BY THE FANS.

The carbonic acid evolved by the respiration of an audience is diluted with air to a degree depending upon the volume of fresh air introduced by the fans.

If, therefore, we know the proportion of carbonic acid in the external air and in that of an apartment, and also the number of individuals present, we can calculate, approximately, the volume of air which has been introduced. This is the chemical determination of the degree of ventilation; it has been effected by Roscoe, for his experiment No. IV, in the following manner:

If we assume, as an average of the experiments performed by different observers, that a man exhales 0.686 cubic feet of carbonic acid per hour, 16 men will exhale in six hours 65.86 cubic feet, and it is required to know with how much air, containing 0.04 per cent. of carbonic acid, these 65.86 cubic feet must be mingled to yield an air of 0.1242 per cent. of carbonic acid, as found by the analysis. Since the fresh air to be added contains carbonic acid, we require more of it that we would need were it free from that gas.

Let V represent the volume of air free from carbonic acid that would be required, and a the fraction which the impurity in the air (0.04) is of the limit of impurity in the mixtures (0.1242:) and let V^1 represent the volume of normal air that we require, then:

$$V^1 = V + V\,a + Va^2 \;.\;.\;.\;.\;.\; + V^n$$

It will be sufficient to calculate the three first terms only of this expression:

$$0.1242 : 99.8758 :: 65.86 : V = 52961.7;$$

$$a = \frac{0.04}{0.1242} = 0.322;$$

$$\text{and } a^2 = 0.103684.$$

Employing these numbers in computing the value of V^1, we find that V^1 is equal to 75,500 cubic feet of fresh air which have passed into the room in six hours, carrying off 0.1242 of its bulk of carbonic acid.

This volume of air is equal to a ventilation of 13.1 cubic feet of air per man and per minute, and was found sufficient (by observation) to remove all unpleasant odors.

By a direct experiment upon the velocity of air escaping through the chimney, Roscoe found a ventilation from this source equal to two cubic feet per man and per minute; consequently the bulk of vitiated air passes off through accidental sources of ventilation, such as crevices in the doors and windows, and by diffusion of the carbonic acid through the walls.

Calculation of the ventilation of the Senate by the chemical method.—In Roscoe's calculation he obtains the number 76,600 for the cubic feet of air in six hours instead of 75,500. The former gives to each man a volume of 13.3 cubic feet of air per minute. He employs in his computation 0.585 cubic feet of carbonic acid per hour as the quantity exhaled by an average man, while upon a previous page he accepts 0.699 cubic feet as the mean of the experiments of several observers. In the following calculation let us assume the latter number, and suppose that 1,000 persons were present in the Senate chamber upon the evening of February 24, 1865, when experiments 66, 67, 68, 69, and 70 were performed.

By these experiments the carbonic acid in the external air was 2.648 per 10,000, and the proportion of this gas in the air collected on the floor was 4.557; consequently $e = \frac{0.02648}{0.04557}$. A thousand men will exhale 699 cubic feet of carbonic acid in an hour: V, therefore, will equal 2,639,030 cubic feet; and V' will be found by calculation to equal 5,073,619 cubic feet of fresh air required in an hour, or 84,560 cubic feet per minute, to reduce the carbonic acid exhaled by 1,000 men to a dilution of 0.04557 per cent. This is equal to 84½ cubic feet per man and per minute.

The power of the fan has been estimated by its builders at 60,000 cubic feet per minute, or 60 cubic feet per person for a thousand individuals.

I have assumed an audience of only 1,000 persons in this calculation, which is probably too low, as the floor and galleries were crowded, as is usual toward the close of the session.

An audience of 1,400 persons would have 60.4 cubic feet per minute for 84,550 cubic feet of fresh air; consequently the inference from the chemical method of determining the amount of ventilation shows that the fan possesses the power that it was supposed to have.

Experiments upon the velocity of the air leaving the fan.—I regret, for the want of a delicate wind-wheel, to have been unable to test directly the velocities of the air-currents in the air-ducts of entrance and exit. My experiments do not, indeed, leave any question as to the amount of ventilation unanswered, which would have been settled by such an investigation, but it would have been interesting to have compared the results afforded by the velocities and by analyses.

I performed, however, the following experiments with an anemometer, or syphon manometer, placed at my disposal by the architect, upon the velocity of the air as it enters the main duct, applying the instrument to a hole which I found prepared for it in the fan-room:

IV. VELOCITY AND QUANTITY OF AIR ENTERING THE MAIN AIR-DUCT OF THE HOUSE OF REPRESENTATIVES.

Table of results for March 30, 1865.

Revolutions of the fan per minute.	Velocity of the air—feet per second.	Cubic feet of air—feet per minute.	Cubic ft. per minute, less one-tenth.	Cubic feet of air per minute and person, for 1,000 of audience.
45	18.08	61694	55525	55.5
50	21.52	73430	66087	66.0
60	23.48	80117	72105	72.1
65	25.26	86215	77593	77.6

As the results of the analysis in the House of Representatives did not differ much from those of the Senate, we may find a confirmation of the degree of ventilation, as calculated by the chemical method, in the results of these experiments upon the velocity of the air current.

With a moderate degree of care in the management of the fan, we can be sure of at least from fifty to sixty cubic feet of air per minute and person,* which is an excessive amount of ventilation, as will be seen from a consideration of what has been proposed and effected in Europe. With this velocity I have not, in moving about the halls to perform the experiments, perceived any unpleasant currents, which is, of course, an important consideration.

V. THE DEGREE OF VENTILATION EXISTING IN SOME OF THE PUBLIC EDIFICES OF EUROPE.

Several of the public edifices of Europe have been subjected to a careful examination by scientific men of the first rank as to the degree of ventilation existing in their apartments. It is interesting to compare the results obtained, and the volumes of air deemed necessary for a proper ventilation, with those of our Capitol.

Péclet, Morin, and others devoted to this branch of investigation, arrive at the actual amount of fresh air introduced by an examination of the velocity of the air currents entering and leaving the apartment.

That degree of ventilation is deemed sufficient which permits no persistence of bad odor in the place to be ventilated.

This, however, is a very uncertain criterion, and the only correct method of ascertaining the proportion of fresh air needed for a perfect ventilation would result in combining the study of the velocity of the air currents with the determination of the relative amount of carbonic acid in the air of the inhabited apartment, which has, in fact, been effected in the present investigation.

Judging from the odor, General Morin assumes that 23.5 to 35.3 cubic feet of air per minute and patient are scarcely sufficient for the ventilation of the hospital Beaujon;† and Péclet, in criticising these results, thinks that they are too high, and hopes for the sake of humanity that some other source of insalubrity, as unwashed bed-clothes or unwhitewashed walls, made the necessity for so large a ventilation improperly apparent.

Peclet himself assumes from 5.9 to 11.8 cubic feet per person and minute as a proper ventilation; and yet, according to the experiments in the prison Mazas, this quantity was insufficient to restrain the odor of the close-stool, when without water, from the cell, while 3.5 cubic feet of air per minute were insufficient to remove the odor under any circumstances.

An odorous body, such as musk, or as may be found exhaling into the air from unclean, or even from some kinds of clean men, will assert itself against even a powerful ventilation. If an odor be manifested for a few minutes and then be removed, we can judge of the degree of ventilation from the rapidity with which it becomes imperceptible; but if the perfume be constantly emitted, we can draw no such conclusions.

In a close and badly ventilated bedroom the *unpleasant odor* perceived the next morning upon entering it from the fresh air is not from the substance which is the cause of its insalubrity, but is an index or measure of the carbonic acid also present, and which is in too great excess for health. The physiological effects or physical symptoms of a bad ventilation are the same as those produced by carbonic acid. We cannot yet correctly estimate the part which morborific emanations from the body, or miasmatic substances in the air, perform to cause disease. The former would, of course, be removed from an apartment by ventilation; but atmospheric miasms would be brought to the individuals of an audience more abundantly the greater the ventilation. With respect to the actual degree of ventilation necessary for health there is great difference of opinion. In estimating this amount for an assemblage of persons we can, of course, only regard the average man. As Dr. Luther Bell (Ventilation, p. 104) correctly states, we must strike a mean of ventilation and heat. "The rubicund, four-bottled country squire, and the exsanguined and aged ecclesiastic, cannot be measured by the same scale without one or the other suffering."

The following volumes of air in cubic feet per person and minute have been assigned by different experimenters:

Dr. Arnott	2 to 3
Tredgold	4
Mr. Toynbee	10
Dr. Bell	10 to 25
Peclet, according to circumstances	10 to 20
Peclet, at least	5

* Mr. Robert Briggs, one of the builders of the ventilating machinery, calculates the minimum ventilation of the halls at 50,000 cubic feet of air per minute for the hall of Representatives and 30,000 for the Senate, and the maximum amount, for summer use, at double these volumes.

† In the hospital Lariboisière, from the mean of the results of three experimenters, 41.5 cubic feet per minute and patient were afforded. (Morin Études sur la Ventilation, p. 118; ed. 1863.) To make the results comparable, I have reduced all cubic meters per hour per person to cubic feet per minute and per person, (cubic meter=35.32 cubic feet;) also temperature to Fahrenheit.

Roscoe, (insufficient in barracks)	10
Roscoe requires at least	20
Dr. Reid, (minimum)	10
Dr. Reid requires, according to circumstances	20 to 60*
Vierordt	2½

In a pamphlet on the laws of health, by Dr. E. A. Parker, reviewed in Qr. Jour. Science, January, 1865, the author concludes from the results of a number of experiments (made by others) on the quantity of carbonic acid expired and of oxygen consumed during twenty-four hours by a human being, that in order to render the products of transpiration and respiration inocuous, 33¼ cubic feet of fresh air per minute are required. And when gas-lights are burning in a room, it must be remembered that each flame consumes as much oxygen and gives out as much carbonic acid as *five* human beings.

Peclet estimates the space occupied by an average individual at one square foot of floor-surface, and calculates the height of a room to contain an hour's supply of fresh air upon this basis, at fifty-four feet.

In Peclet's *Nouveaux Documens Relatifs au Chauffage et à la Ventilation des Etablissements Publics, Paris*, 1853, may be found the following results of experiments performed upon the degree of ventilation of certain apartments in France:

In the prison Mazas, examined by a commission of scientific and practical men, three and a half cubic feet of fresh air per minute were found insufficient to maintain the purity of air in one of the cells. A ventilation of 5.9 cubic feet was deemed satisfactory for the cell with one inmate with a burning candle, which gave, by experiment, a proportion of carbonic acid in the air equal to four and a quarter times (by volume) the quantity existing in the external atmosphere. For this degree of ventilation the temperature of the apartment conducive to health and comfort was placed at 60° Fahrenheit.

The church of St. Roche, examined by a commission during the winter of 1845–'46, was found to have a capacity of 32,000 cubic meters. Its ventilation was at the rate of 10,000 cubic meters per hour, and renewed the air eight times during the day. As the church would contain 3,200 persons, it would afford to each person 10 cubic meters of air for an hour; that is, 5.9 cubic feet per minute.

The Salle des Sciences de l'Institut, examined by M. Cheronnet, with an audience of one hundred and eighty persons, and ventilated by the draught of a chimney, according to the plans of Mr. Duvoir-Leblanc, afforded to each person per minute 16.6 cubic feet of air. In a second experiment the volume of air afforded was 17.3 cubic feet.

L'hôpital du Nord.—A commission of *savans* appointed to decide upon different plans submitted for the ventilation of this hospital, accepted that which gave to each bed per minute from 11.8 to 23.5 cubic feet per hour.

Experiments upon the large lecture-room of the Conservatoire des Arts et des Métiers, by General Morin, yielded the following results, (Peclet Op. cit., p. 49:)

For the most active ventilation.

February 14	For 775 persons	8.88	Cubic feet per minute and person.		
February 18	For 850 persons	8.83	Do.	do.	do.
February 27	For 800 persons	9.18	Do.	do.	do.
Mean		8.96	Do.	do.	do.

For the less active ventilation.

March 7	For 800 persons.	5.24	Cubic feet per minute and person.		
March 8	do do	5.41	Do.	do.	do.
March 12	do do	6.47	Do.	do.	do.
Mean		5.71	Do.	do.	do.

General Morin has published some experiments upon the lecture-rooms of the Conservatoire, later than the preceding, in the Comptes Rendus for 1853, (vol. lvi, p. 201.) These apartments are, a large rectangular one, capable of containing from 700 to 800 persons, and a smaller one, which is semicircular, and which will not accommodate more than 400 individuals. They are warmed by a hot-air furnace, and are both ventilated by the draught of one chimney. The ventilation is principally a downward one. Particular experiments demonstrated that a temperature of 64.4° Fahrenheit was insuffi-

*Reid required for British House of Commons 60.

cient for the comfort of either the lecturer or of the audience, but had to range from 68° to 69.8° Fahrenheit. The mean temperature of the rooms, in two series of observations with a variable number of auditors, was, for the first series, 67.64° Fahrenheit, and for the second series, 67.46° Fahrenheit. In the smaller room there were furnished 56.9 cubic feet of fresh air per minute and person. In the large room this volume was 14.38 cubic feet. In the smaller room there was no odor in the air, either of the apartment or of the exit-duct. In the larger room the air was free from odor, but the smell was perceptible in the exit-duct. From these experiments Morin infers the necessity of a *minimum* ventilation of 14 cubic feet per person and minute. General Morin has also (Comptes Rendus, lvi, p. 365, 1863) investigated the ventilation of the new theaters of Paris with the following results:

Théâtre Lyrique.—September 24, 1862, temperature, 71.6° Fahrenheit; and that of the external air, 62.2°; ventilation, 24.01 cubic feet per minute and seat. By a second experiment, December 9, temperature, 71.6°; of external air, 46.4° Fahrenheit; ventilation, 24.02.

Théâtre de la Gaîté.—January 13, 1862, air evacuated per seat, per minute, equaled 17.17 cubic feet.

Théâtre du Cirque.—August 11, 1862. The air evacuated equaled 21.19 cubic feet per minute and seat. When examined again, on January 13, 1863, after the adoption of an ill-advised plan, the ventilation had fallen to 10.47 cubic feet.

The Chamber of Peers of France, in the Luxembourg palace, was ventilated by M. Talabot, in 1860, upon plans tested and approved by Thenard, Gay Lussac, Pouillet, and Peclet. The current is determined by a pair of fan-wheels, aided by a gas-burner placed in a circular aperture in the ceiling. The apparatus in full action withdrew 425,700 cubic feet per hour. In summer the ventilation is effected by the aid of an additional pair of fans, the gas-burner being disused. The ventilation varies from 7 to 12 cubic feet per minute and person.

In the Pentonville Model Prison the ventilation yields from 30 to 45 cubic feet per minute to each person.

Hood (Warming and Ventilation, p. 251) estimates the air required for ventilation by the amount needed to take up the moisture from the skin and lungs. The air required for respiration (*i. e.*, oxidation) is very much less than that needed to hold in solution the vapor of the skin and lungs, which evolves 12 grains of water per minute.* If the temperature of a room be at 60°, with a dew-point of 45°, a cubic foot of its air will absord 2¼ grains of vapor; or, in other words, the perspiration from the body will saturate 5⅓ cubic feet of air per minute. If, however, we take the dew-point lower, say not to exceed 20° or 24°, then 3¾ cubic feet of air per minute will be required to carry off the insensible perspiration; while for the pulmonary supply ¼ cubic foot will be needed, making a total of four cubic feet. In summer, as the dew-point is higher, more air will be needed, viz, 5 cubic feet per minute for summer ventilation.

From the preceding examples, calculations, and considerations, it will be admitted that the degree of ventilation of the Capitol extension is superior to any of the halls described in respect to the volume of fresh air furnished.

The House of Representatives, with a capacity of 465,372 cubic feet, may be supplied with 60,000 cubic feet of air per minute, which will change the whole air every seven minutes and furnish to each of a thousand persons 60 cubic feet per minute.

This amount of ventilation appears to be excessive, and I think that it might be diminished with advantage and economy, if the chief defect of the air, viz, its want of moisture in the winter, were remedied.

III. UPON RESPIRATION.

It is not possible, nor is it, indeed, necessary, to enter, in this report, upon the interesting question of the physiology of respiration. Some remarks may, however, be permitted.

I. PRODUCTS OF RESPIRATION.

Professor Miles, in his report upon the ventilation of dwelling-houses and schools, assumes that if the temperature of the air range from 65° to 70° Fahrenheit, we will have the following average results for the—

Respiration of an adult:

Number of respirations per minute	20
Cubic inches of air inhaled at each respiration	20
Cubic inches of air inhaled per minute	400
Cubic inches of oxygen at each respiration	4
Cubic inches of oxygen per minute	80

*According to Seguin, the maximum loss of water during 24 hours from the lungs and skin, as insensible perspiration, is, for an individual, 5 pounds, the minimum being 1¼ pounds. The average exhalation per minute is, for the lungs, 7; for the skin, 11; total, 18 grains. Carpenter (Physiology, p. 532) assigns six grains per minute as the average exhalation of water by the lungs. (See, also, v Gorup Besanez Physiologie.)

Products respired:

1. Damaged atmosphere with nitrogen in excess.
2. Fifteen cubic inches of carbonic acid gas.
3. Three grains of vapor of water.
4. The surrounding air is vitiated by the mixture of the products of respiration with it at the rate 2½ cubic feet per minute.

The quantity of air inhaled at each respiration has been found to be different by different observers, owing to the difficulty of determining it with accuracy; thus:

Herbert assigns	20	to 30	cubic inches
Valentin	14	92	"
Vierordt	10	42	"
Coathupe	16	..	"
Hutchinson, average	16	20	"
Hutchinson, extreme	7	77	"

Assuming 20 cubic inches to be the average quantity, the volume of air remaining in the lungs, and which *cannot* be expelled, is estimated at from 75 to 100 cubic inches, and the quantity which can be expelled by a *forced expiration* is as much more; the sum of the two being from 150 to 200 cubic inches, which is from 7½ to 10 times the breathing volume. From these considerations it will be perceived that something more than the respiratory act is required to exchange for oxygen the carbonic acid contained in the lungs. This exchange is effected by the law of the diffusion of gases, a phenomenon which takes place with great rapidity. (Carpenter's Physiology.) Draper (Physiology, p. 153) found that a little bubble of shellac blown upon the end of a glass tube permitted the passage of ammonia. If a bottle be rinsed out with ammonia, and a soap bubble be blown in it by means of a glass tube, a rod moistened with hydrochloric acid placed at the other end of the tube gives *instantaneous* evidence of the presence of ammonia by the formation of copious white fumes. Thus a rapid change of the air in the lungs is effected. Grehaut (Comptes Rendus, lv., p. 278) finds the act of respiration to be a true ventilating process. He inhaled a certain volume of hydrogen gas, and determined, in the same volume of exhaled gases, the proportion of air and hydrogen. It followed that, by the inhalation of 500 cubic centimeters of pure air, the same volume, by expiration, contains ⅕ of pure and ⅘ of spoiled air; also that the ⅘ of pure air remaining in the lungs become uniformly diffused through the air-passages after two respirations. The total volume of air respired daily varies, according to different authorities, from 356½ cubic feet to 398½ cubic feet; whence 800 cubic feet have been assigned as the minimum quantity of air that can be safely allowed for each individual confined in any room. (Carpenter.) Air which already contains carbonic acid does not exchange by diffusion and endosmosis with that vitiated in the lungs as readily as pure air. Messrs. Allen and Pepys found that when 300 cubic inches of air were respired for *three minutes*, only 28 cubic inches of carbonic acid were found in it, although the previous rate of its production, taking the air fresh at every respiration, was 32 cubic inches per *minute*. The unhealthfulness of unventilated rooms, therefore, increases in a larger ratio than the respective amounts of carbonic acid found in them.

II. THE AMOUNT OF CARBONIC ACID EVOLVED IN RESPIRATION

is important, as it enables us to calculate the amount of fresh air needed in an apartment to maintain a proper degree of purity. In the calculation from the data of my experiments (p. 62) I have assumed, with Roscoe, 0.699 cubic feet per hour (= 0.01165 cubic feet per minute) as the amount of carbonic acid exhaled by an average man.

This is the mean of experiments by Scharling, who obtained 0.618, and of Vierordt and Hutchinson, who obtained 0.780 cubic feet per hour. Andral and Gavaret, (Jour. Pr. Ch., xxix, 331,) Scharling, (Id., xxxvi and xlviii,) Hervies and Saint-Sager, (Comptes Rendus, xxviii, 250,) and others, have published experiments upon this subject, from which it appears that the variation in the amount of carbonic acid exhaled from the lungs and skin depends upon the temperature of the surrounding medium, age, sex, development of the body, state of health or disease, muscular exertion or repose, sleep or watchfulness, period of the day, and state of the digestive process.

Laissaigne, (Jour. Pr. Ch., xlvi, p. 287,) by a calculation based upon the analysis of the air of an unventilated room, having deducted the carbonic acid normally in the air, and having allowed for the air displaced from the room by the audience, (the bulk for an average man, with clothing, having been ascertained, by immersion in a bath, to be 2¾ cubic feet,) determined the exhalation of *carbonic acid* to be 1,083.86 cubic inches for the average man in health, or a little less than ⅓ of his own volume per hour.

This agrees with the experiments already given by Scharling, which, in cubic inches, is 1059.2, and is not far from those by Vierordt and Hutchinson, which are, cubic inches, 1,348; mean, 1,209 cubic inches per hour.

By a similar calculation upon the air of stables, he found that a horse breathes out

13,409 cubic inches, or 0.328 of his volume, in carbonic acid per hour, and that the ratio of the hourly quantities exhaled by a man and by a horse are as 1 to 12.3.

An ox exhales in an hour	16,545 cubic inches carbonic acid.
A ram, of eight months	3,371 cubic inches carbonic acid.
A goat, of eight years	1,311 cubic inches carbonic acid.
A kid, of five months	708 cubic inches carbonic acid.
A hound	1,117 cubic inches carbonic acid.

Pettenkoffer and C. Voit (Kopp and Wills Jahresberieght, 1862, 523, and 1863, 635) have made an extensive series of observations upon the respiration of dogs, in the "respiration and perspiration apparatus," constructed in Munich by the munificence of the King of Bavaria. They found that atmospheric air contains (normally) no other appreciable carbon compound except carbonic acid, and that the proportion of hydrogen is also inappreciable. For every 416–428 grams of carbonic acid in the breath of dogs, they discovered from 4.3 to 7.2 of *hydrogen*, and from 3.7 to 63 of hydrocarbons. They found that the sum of the carbon, hydrogen, oxygen, and nitrogen expelled from the body in 24 hours was equal to the sum of these elements taken in the food. They observed also that the separation of carbonic acid by the skin and lungs exhibits a considerable variation in quantity; thus, by a generous diet, they found three times the quantity than obtained after a ten day's fast.

J. Reiset, (Comptes Rendus, lvi, 740,) who investigated the process of respiration upon calves, sheep, hogs, and turkeys, found that, in a close stable, having a capacity of 133¼ cubic meters, and containing 50 sheep, the air, after one hour and ten minutes, contained one per cent., and after twelve hours, 10 per cent. of carbonic acid; so that, if the respiration could have continued in this proportion, the whole of the oxygen would have been converted into carbonic acid in 25 hours.

Dr. E. Smith, (Proceedings Royal Soc., ix, 611, 638,) in his "Inquiries into the Phenomena of Respiration," observed the quantity of air inspired, and of carbonic acid expired, together with the rate of pulsation and respiration, noting—1st. The phenomena during the 24 hours with and without exertion and food. 2d. The variations from day to day and for the season. 3d. The influences of particular kinds of exertion.

The experiments were performed upon himself and upon three other persons; the results are stated in weight. The quantity of carbonic acid expired in 24 hours varied from 24.274 ounces to 16.43. In a light sleep it was from 4.88 to 4.99 grains per minute, and the total evolution in the six hours of the night was 1,950 grains. The quantity of air inspired varied from 588 to 355 cubic inches per minute, the depth of inspiration being from 30 to 39.5 cubic inches. The respirations were, to the pulsations, as 1 to 4.63 in the youngest, and as 1 to 5.72 in the oldest.

One-half of the product of the respirations into the pulsations gave nearly the cubic inches of air inspired by some of the persons.

The proportion of the carbonic acid to the air inspired varied from 1 : 54.7 cubic inches to 1 : 58.

The variations of the carbonic acid evolved during the working day yielded an average maximum of 10.43 and a minimum of 6.74 grains per minute. This quantity increased after a meal, and decreased from each meal, so that the minima were nearly the same, and the maxima were the greatest after breakfast and tea.

The hot season caused a diminution of all the respiratory phenomena. The maxima were in spring, and the minima toward the close of summer, with periods of decrease in June and of increase in October.

In the author the diminution amounted to—

In the quantity of air	30 per cent.
In the rate of respiration	32 per cent.
In the quantity of carbonic acid	17 per cent.

The maximum influence of the food upon the respiration was observed to be effective within two and a half hours after its reception.

III. ON THE DIRECTION THE PRODUCTS OF RESPIRATION TAKE AFTER LEAVING THE BODY.

It does not enter within the scope of this report to pronounce an opinion upon the different methods of ventilation. Having tested it and approved its efficiency, I am absolved from the responsibility of advising the adoption of any different plan from that which exists in the Capitol. Before this conclusion was reached through the experiments, I made the following observations upon the course of the breath after it leaves the body:

Mr. Goldsworthy Gurney, in his testimony before a committee of the House of Commons, asserts that the breath is forced downward through the nostrils *to the ground*, which is the natural provision against breathing the same air over again. He proves

the fact by tracing the downward course of the current by the condensation of the breath of the nostrils on a frosty day. This opinion is quoted by those authors who approve of the downward system of ventilation, and it is given, also, in an admirable treatise upon the elements of ventilation, contained in a report by Messrs. Shedd & Edson to a committee of the Massachusetts legislature.

The conditions are different for a person in the external air and when in a room raised to a comfortable temperature. In the former case the breath, nearly saturated with moisture from the temperature of the body, parts with a large portion of its water by the action of the hygrometric condition of the cold external air. These particles of water thus produced are specifically heavier than air, and their tendency to fall is assisted by the downward impulse from the nostrils.

The experiment, to be fair, should be performed in the room, and at the temperature concerning which the practical conclusions are drawn. On March 27, 1865, at 1½ p. m., in the laboratory of the Smithsonian Institution, the temperature of which was 59°.26 Fahrenheit, a delicate thermometer, held in the hand for several minutes, indicated 95°.36 Fahrenheit. Held in the same mouth, and observing the degree by the aid of a mirror, it indicated the same temperature. Upon smoking a pipe with a stem of wood six inches long, slowly, with the thermometer also in the mouth, the temperature did not sensibly rise. Having thus obviated a source of error from any supposed heat in the tobacco smoke, I experimented upon the air currents of the breath, both while sitting and standing, following them readily by aid of the smoke.

Before expulsion the smoke was held in the mouth for a short time to insure its temperature to be the same as that of the breath, and the hot pipe was held or placed aside. When the smoke is expelled gently from the nostrils, as in the act of breathing, it proceeds downward for a foot or less, and then rises rapidly. It rises more rapidly when in the sitting posture by reason of the current of warm air ascending from the legs.

When the smoke is blown with great force through a glass tube, it can be made to reach the ground, but the tendency after it loses its momentum is still upward. Blown horizontally, it rises as soon as the horizontal force is exhausted, which depends upon the force of the blast. The smoke blown upward through the glass tube rises very rapidly, as may be seen also by the rings of smoke which some persons delight to produce.

After the experiment the smoke hangs about the ceiling, disappearing gradually.

These experiments, which any one may repeat, appear to settle the question of the upward tendency of the breath if any proof be needed.

IV. THE MOISTURE IN THE AIR.

I. GENERAL CONSIDERATIONS.

For an atmosphere which shall be salubrious to the inmates of an apartment, the hygrometric condition of the air is as important as its freedom from poisonous or deleterious gases. The experiments have shown the air of the Capitol to be as deficient in this respect as it is excellent in regard to the degree of ventilation afforded. In fact, the deficiency of aqueous vapor is, in a measure, due to the abundance of the ventilation, for the dry air of winter, having its capacity for moisture increased by warmth, is forced through the halls with such liberality as to carry off not only the carbonic acid, but also the water arising from respiration.

The evaporation of water from the body is intimately connected with health. The sudoriparous glands, which are constantly secreting their liquid, have a length of tubing which has been estimated at twenty-eight miles. The secretion takes place so gradually that the water ordinarily evaporates as insensible perspiration as soon as it reaches the exterior surface of the skin.

During severe exercise, exposure to great heat, in some diseases, or when the evaporation is hindered by an impermeable covering, the secretion collects upon the exterior of the body in drops of sensible perspiration.

The total average loss by the lungs and skin in twenty-four hours is almost 3½ pounds of water, of which somewhat more than ⅔, say 2¼ pounds, are furnished by the skin. Of these 2¼ pounds, only ⅓ is furnished by the vital process of secretion, by the sweat glands, for the greater part of the moisture transudes through the skin by simple evaporation. The cutaneous and urinary excretions are, as is well known, vicarious. The evaporation from the skin regulates the animal heat, the body being in an analogous condition to those porous earthen jars in which the inhabitants of tropical climates cool water by the evaporation of that portion which exudes to the surface of the vessel.

The estimated loss of heat to the body by evaporation, per minute, is sufficient to raise a half a pint of water from the freezing to the boiling temperature.

For health the body must evaporate a quantity of water within certain limits. The amount evaporated is influenced by the hygrometric condition of the air and by the state of the body itself. The evaporation is increased by muscular action and by a dry atmosphere; it is diminished by repose and by a moist air.

If the functions of the skin are interrupted, certain diseases are manifested. Among these are affections of the throat, catarrh—passing into acute bronchitis—pulmonary consumption, pericarditis, inflammation of the stomach and bowels, dyspepsia, rheumatism, gout, and fevers.

"In the climate, or we might say rather climates, of the United States, every possible means ought to be enlisted for enabling the inhabitants to bear up under the two extremes, constituting two contrasted climates, of great summer heat and great winter cold. The influence of one is so powerful and sufficiently prolonged as to render us susceptible invariably to the other; and we, in the Middle States, are nearly in the situation of those who should spend their summers in Egypt and their winters in Russia."*

Our country has a different climate, in respect to moisture, from those parts of Europe which have the same temperature.

Desor (Du Climat des États-Unis et de ses effets sur les habitudes et les mœurs. Actes de la Soc. Helvet. des Sc. Nat., 1853) has endeavored to show the influence of our dry climate upon the manners and customs of our people, and the difference in this respect as it appears to an European.

"The German immigrant finds that the wash dries faster; the bread which at home could be preserved for several weeks, becomes useless in a few days; the crops are more uncertain; the cabinet-makers find that their wood, which, according to the experience of the old country, was deemed sufficiently dry to be made up into furniture, warps, in Boston and New York, in a short time; further, that they must employ stronger glue in America."

Desor supposes that the influence of our comparatively dry climate stamps its impress upon the people; thus "the North Americans are, for the most part, spare, and with long necks. Europeans, in America, become speedily more lean, and Americans, in Europe, more fleshy. The European who arrives in New York, Boston, or Baltimore, is surprised at the feverish activity everywhere prevailing. Everybody is in a hurry, and the persons on the street run rather than walk. In some of the larger cities of England a similar condition is apparent; but the activity of the Englishman appears more deliberate; that of the Yankee more instinctive, and rather the result of a natural impatience than from necessity. The Americans, even with leisure, scarce take time to eat their meals. In spite of their apparent coldness, they are more excitable than the Europeans, and their sensibility is proverbial."

Whatever may be the climatic difference between Europe and America, and its physiological effect upon the people, every one has felt the oppression produced by a low dew-point, and the relief experienced upon the advent of a shower, or by an approach to the ocean or to a lake.

The moisture in the atmosphere may be regarded from two points of view; 1st. As to the absolute quantity present at any time, and for any temperature. 2d. The relation which it bears to a saturation of the air, at the same temperature, with watery vapor.

1st. The absolute amount of water (such as grains in a cubic foot of air) is measured by the depression which it exerts, by making the air specifically lighter, upon the barometric column, and which, in consequence, is taken as its measure. This quantity increases with the temperature, and is greater in summer than in winter.

2d. The relative humidity is expressed in percentages of the saturation of the air for moisture at any given temperature. The warmer the air the greater is its capacity for containing watery vapor. If, therefore, we warm a cubic foot of air which is saturated with moisture, that is, which has a relative humidity = 100, we may attain a relative humidity of, say, 50, or of any number below 100; and, *vice versa*, air posessing a relative humidity of 50 may attain that of 100 by being cooled to the proper degree. The relative humidity is greatest, that is, the air is nearest its point of saturation, in winter, although the absolute quantity of water it contains is then least.

* Dr. John Bell. Treatise on Baths.

The following table of the mean proportion of aqueous vapor in the air of Halle, Germany, will illustrate these principles:

Months.	Tension, in millimeters, of the aqueous vapor, measuring the absolute humidity.	Relative humidity.
January	4.509	85.0
February	4.749	79.9
March	5.107	76.4
April	6.247	71.4
May	7.836	69.1
June	10.843	69.7
July	11.626	66.5
August	10.701	61.0
September	9.560	72.8
October	7.868	78.9
November	5.644	85.3
December	5.599	86.2

Thus, as the tension or absolute humidity increases with the year, the relative humidity decreases.

The following table* expresses, in troy grains, the weight of vapor contained in a cubic foot of saturated air at temperatures of Fahrenheit:

Temperature of air.	Vapor, in grains.	Temperature of air.	Vapor, in grains.	Temperature of air.	Vapor, in grains.
0	0.545	63	6.361	80	10.949
5	0.678	64	6.575	81	11.291
10	0.841	65	6.795	82	11.643
20	1.298	66	7.021	83	12.005
30	1.968	67	7.253	84	12.376
32	2.126	68	7.493	85	12.756
40	2.862	69	7.739	86	13.146
45	3.426	70	7.992	87	13.546
50	4.089	71	8.252	88	13.957
55	4.860	72	8.521	89	14.378
56	5.028	73	8.797	90	14.810
57	5.202	74	9.081	91	15.254
58	5.381	75	9.372	92	15.709
59	5.566	76	9.670	93	16.176
60	5.756	77	9.977	94	16.654
61	5.952	78	10.292	95	17.145
62	6.154	79	10.616	96	17.648

The relative humidity of the air very frequently reaches 100. Very rarely does it fall to 0. Nor is this 0 of observations absolute dryness of the air, but such a degree of it as to be outside of the limits of the tables which have been calculated for the reduction of psychrometrical observations. There are, however, records of extremely dry conditions of the atmosphere (Müller Lehrbuch der Kosmischen Physik, p. 404) in certain places.

1. Thus Humboldt and G. Rosé found on the steppes of Platowskaya air with a temperature of 74°.66 Fahrenheit, and a difference between the dry and wet bulbs of the thermometer of 21°.06. This condition of dryness corresponds to less than 1.957 grains

*Guyot, No. X. Smithsonian Meteorological tables.

of moisture in a cubic foot of air; and since this quantity of water would saturate air of the temperature of 30° Fahrenheit, it follows that the dew-point of the air observed must have been below 30° Fahrenheit. The relative humidity is 15.

2. Abbadie observed at Abbay, upon the Blue Nile, the dry bulb, 98°.70; the wet bulb, 67°.82; difference, 30°.96. This corresponds to 2.662 grains of moisture in the air, which was capable, from the temperature, of holding 18.75 grains; or to a relative humidity of 1.4, and to a dew-point of 38° Fahrenheit.*

3. The same observer found air upon the coast of the Red Sea during a simoom communicating to the dry bulb a temperature of 108°.86; wet bulb, 69°.08; difference, 39°.78. A cubic foot of the air was capable of holding 18.66 grains of moisture, but contained only 1.66 grains. It had, consequently, a relative humidity of 0.9, and a dew-point of 26° Fahrenheit.*

Such a degree of dryness is very unusual, and is much greater than that occasionally observed, and which is indicated by a relative humidity of 0 in meteorological reports, because the tables do not extend to the calculation of such low humidities.

Character of the air of the Mammoth Cave.—The following observations, made during a visit to the Mammoth Cave of Kentucky in the year 1855, and which are now for the first time published, have a bearing upon the temperature and hygrometric condition of an agreeable and bracing atmosphere. During the afternoon of July 17 the short route was accomplished, which embraces the points of interest not very remote from the entrance to the cave. The temperature of the external air was at 82° Fahrenheit.

During the summer season, as is well known, a current of air, which at the door of entrance is so strong that the flame of a candle is kept alight with difficulty, issues from the cave. In the winter season this current is reversed, thus exhibiting a ventilation due to the heating effect of the sun upon the earth.

In the draught of air which issued from the mouth of the cave and at a distance of about one hundred feet from the door, the thermometer stood at 72°. At the dripping spring and trough inside of the cave, the temperature was 66°. At the first saltpeter vat it was 60°, and at a short distance beyond this point it was 59°. Thus, as the visitor enters the cave, he becomes accustomed to the gradually falling temperature, and no shock is experienced in passing from an atmosphere of 82° to one of 58°. At the second saltpeter vat the dry bulb indicated 58°, and the wet one 56°, corresponding to a relative humidity of 87.6, according to Guyot's tables. The temperature of the small spring called Lake Purity was 55°. The temperature and relative humidity of all parts of the cave visited at this time were, respectively, 58° and 87.6, with the exception of the Star Chamber, which is situated near the houses built for the residences of consumptives. Here the temperature of the air was 59°, and that of the wet bulb was 55°, agreeing to a relative humidity of 76.1.

On July 18 the long route was taken in the company of a friend and with an intelligent guide. We entered the cave at 8½ a. m., and left it at ten minutes before 5 p. m. The distance traveled was estimated by the guide at eighteen miles, and although upon our feet constantly, with the exception of a short rest at dinner time, and with a delay sufficient for a bath in Lake Lethe, and sometimes using considerable exertion, we did not experience great fatigue. The temperature of the external air was 82°. In the cave from Echo River to Martha's Vineyard the mercury stood almost constantly at 58°; but in two or three instances 60° was indicated, and upon one occasion the temperature was 57°. The temperature of the water of Hebe's Spring was 56°. From Martha's Vineyard to Cleveland's Cabinet the thermometer indicated 58°. In the end of the cave, at 12*h.* 35*m.* p. m., the dry bulb stood at 58°, and the wet one at 56°, corresponding to a relative humidity of 87.6. In Washington Hall, at 2 p. m., after our dinner, the dry bulb equaled 57°; the wet bulb 56°, or relative humidity 93.6, by one observation. At 4 p. m., on the shore of Lake Lethé, dry bulb, 58°; wet bulb, 56°; relative humidity, 87.6. We caught, in the above lake, two fishes and a craw-fish, without eyes, and in the end of the cave a cricket and several other insects having eyes. The proprietor would not permit a survey of the cave to be made, as it was supposed that another entrance existed upon the property of some other person, and of which rumor indicated the situation in or near the end of the cave. The insects with eyes found at this point appear to confirm this view. Such an opening in the cave would seem to be necessary to effect its ventilation. No currents of air were perceptible to the senses inside of the cave, nor was any carbonic acid discovered at the bottom of the deep pits, which were tested by throwing lighted papers into them. This cave presents the example of a bracing and salubrious atmosphere in the summer season, which qualities appear to be due, first, to its lower temperature of 58°, and, secondly, to its suitable proportion of moisture, which corresponds to a relative humidity of 87.6. The fact of its bracing property is abundantly shown by the experience of the numerous visitors, many of whom are delicate women, who make the excursion of the long route in a single day without suffering greater fatigue than a few hours of similar labor in the external air would produce.

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* By Guyot's tables.

The houses built for the consumptive patients were located in the dryest portion of the cave, where the temperature of the air was slightly higher, (one degree,) and its relative humidity 76.1, or less than in the remaining localities visited by me. The failure of the beneficial effects upon the sick, which were expected from a residence of consumptive patients in the houses built in the cave, arose not from the character or quality of the air, but from the need for sunlight, the effect of which was especially severe upon constitutions debilitated by disease.

An atmosphere of 58°, and a relative humidity of 87½, although most agreeable for exertion in the summer time, would scarcely answer for a legislative hall, were it even readily to be attained. During the warm weather a few degrees less than the temperature of the external air would prove pleasant, and the fall of temperature at that season would yield a greater relative humidity. In the winter season, in such a hall, the production of a summer atmosphere without the moisture proper to that season can only give rise to sensations of discomfort and provoke disease. The relative humidity found in the Mammoth Cave corresponds in amount to what has been, from other considerations, shown to be the most agreeable.

The rapidity of the evaporation of the body depends *principally* upon the low relative humidity of the air at a high temperature, and upon the maintenance of this condition in the neighborhood of the body by the action of currents of air. Thus, with too great dryness of the air, particularly at the elevated temperature, and especially if it pass rapidly over the body, there will be a greater degree of evaporation than is consistent with health. On the other hand, in an atmosphere saturated with moisture, the evaporation from the body would be reduced to a minimum, and would be practically nothing in such air having the same temperature as the body. Although we may bear with impunity these extremes for a short period, a persistence in such conditions would be fraught with danger.

In the external air of winter the body cools more rapidly than in summer from the difference of temperature. We regulate the expenditure of animal heat by our clothing, and in summer we do not consume in our bodies as much or as heating fuel, in the shape of food, as in winter. The winter air, though *relatively* moist, is *dryer* than the summer atmosphere in respect to the weight of vapor dissolved in a cubic foot of air. If, therefore, we raise this cold air, as in our dwellings, to the temperature of summer, thereby increasing its capacity for moisture, a much dryer air than that of summer is the result if we do not at the same time add water to it. In an ordinary dwelling-room, with the low degree of ventilation which is sufficient for a few persons, and with a stove or grate in the apartment communicating a different degree of heat to different parts of the room, the desiccating effects alluded to are not so perceptible. The inmates select naturally that part of the room which is comfortable to them, and the moisture arising from respiration is not, to a great extent, withdrawn from the room, but is extended to all parts rapidly by diffusion. When a large volume of dry air is introduced by means of a hot-air furnace, (especially if without the addition of water,) the products of respiration being rapidly carried away, and the temperature of the room becoming uniform, so as to deprive its inmates of the advantages of selecting that most comfortable to each, the effects of the rapid evaporation from the body are apparent in the complaints that the "air is *burned*."

Heating the air to a considerable degree cannot injure it for vital purposes, unless by depriving it of ozone, which is oxygen gas in a peculiar condition. There is, however, but little, if any, ozone in the air of dwellings; its function in the atmosphere is unknown to us, but appears to be that of destroying the poison of miasms. The combustion of the animalcules, dust &c., in the air would give the same products of dry distillation as other animal and vegetable substances, a portion of which would be carbonic acid, which would be so small in amount that it would almost escape the most careful observer. In the method of organic analysis by Hess, where a considerable quantity of air is drawn through the combustion tube, the carbonic acid is not found to be greater than by other systems of analysis; and the most delicate experiments have been needed lately to exhibit the reactions of carbonic acid arising from the combustion of the organic matter in the air. As regards the destruction of contagious matters supposed to exist sometimes in the atmosphere, the heating would, by destroying them, produce a decidedly beneficial effect. There is no need of forming improbable hypotheses to account for the insalubrity of a dry, hot furnace air.

The following example will serve to illustrate the hygrometric condition of the external air of winter:

At the Savage mine of Virginia City, when the external air is cold, a large volume, apparently of steam, issues from the mouth of the mine, condensing upon and covering the neighboring objects with water. This phenomenon occurs only in certain conditions of the atmosphere, as when the dew-point is rather high the cold air descends the ventilating shaft, and is warmed and saturated with moisture at that temperature by the earth. When it issues into the cold and nearly saturated air it must part with the moisture with which it is surcharged for a lower temperature, giving rise to clouds of steam.

"If we desire a summer atmosphere in our winter dwellings we should give to it the mean relative humidity of the external air, or rather the mean relative humidity of the summer months, since it is probable that the annual mean does not fairly express the relative dryness of different countries, the winter humidity being nearly the same in all places. In other words, we should adopt the standard which nature extends to us.

Müller (Kosmische Physik) gives the annual mean relative humidity at 75.

Roscoe states that the experience in heating the House of Lords shows that an agreeable atmosphere, as regards aqueous vapor, is found to exist when the relative moisture ranges from 55 to 82; mean, 68½.

The following tables give the relative humidity for Washington City and for Philadelphia. The first table contains the lowest relative humidity and the means for the months of January and June, for the whole year,* and for the series of years. The mean for the series of years is calculated with and also without 1855, which appears to have been a very dry year. The second table gives the results of January, June, the year, and the seasons of the year 1863 in Philadelphia, a city of proverbial salubrity. There is also the general mean of twelve years' observations.

From these observations the mean annual relative humidity of Philadelphia is 68.5; that of Washington is 68.2; but the observations are not for so long a period as for Philadelphia. From these results it would be safe to adopt a relative humidity for the halls of Congress of from 60 to 80, which have a mean of 70°.

In the third table may be found the results of the experiments upon the relative humidity of the Capitol extension.

I have given in them the relations of a cubic foot of air to the moisture—

1st. As to the number of grains of water which it *can* contain in the respective experiments; 2d, what it does contain; and, 3d, the deficiency of water in a cubic foot of air, in the respective experiments, for a relative humidity of 70.

In the last column I have extended the calculation to ascertain the number of pounds of water required to give to 60,000 cubic feet of the air per minute a relative humidity of 70.

1. *Mean relative humidity at Washington, D. C. Results of Meteorological Observations.* 1854–'59, *Vol.* 1. *(Ex. Doc. 36th Congress, 1st session.)*

The means for—	Year.	Maximum generally.	Minimum.			Maximum.		
			7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.
January	1855	100	40	36	54	88	72	87
June	1855	100	59	27	48	83	60	81
The whole year	1855	100	21	0	34	81.8	59.0	79.1
January	1856	100	58	36	56	93	78	83
June	1856	100	68	34	48	84	57	79
The whole year	1856	100	17	18	2	72.3	56.8	73.3
January	1857	100	45	41	43	78	69	76
June	1857	100	47	22	61	82	57	81
The whole year	1857	100	.....	.....	.....	.....	.....	.....
January	1858	100	50	28	56	78	60	74
June	1858	100	64	41	48	79	57	72
The whole year	1858	100	31	14	17	78.0	56.5	71.2
January	1859	100	35	36	40	74	56	69
June	1859	100	42	31	51	75	56	76
The whole year	1859	100	33	12	33	77	56	73

*In calculating the mean relative humidity of different places to compare their relative dryness, it is probable that we should omit the winter months in which the relative humidity is nearly the same in them.

Mean for the years, at all hours.

	For—				Mean for the years.
	1855.	1856.	1858.	1859.	
Relative humidity	73. 30	67. 20	68. 57	68. 67	69. 44
Do	(Omit.)	67. 20	68. 57	68. 67	68. 15

2. *Mean relative humidity of Philadelphia. (From table quoted by Messrs. Shedd and Edson. Report, page* 21.)

1863—Mean results for—	Maximum.	Minimum.	7 a. m.	2 p. m.	9 p. m.	The whole day.
January	100	38	78. 0	65. 3	74. 8	72. 7
June	94	22	67. 9	51. 0	65. 6	61. 5
For the year	100	15	74. 5	56. 7	70. 5	67. 2
Winter	100	29	77. 9	63. 4	73. 5	71. 6
Spring	96	15	72. 3	51. 7	69. 4	64. 5
Summer	94	22	74. 1	58. 5	71. 9	68. 2
Autumn	97	25	75. 1	53. 8	69. 2	66. 0
General mean for 12 years	100	13	76. 0	57. 4	72. 2	68. 5

3. *Table of humidity.—Experiments on the ventilation of the Capitol Extension: Wetherill.*

Number of experiment.	Temperature, air, Fahrenheit.	Relative humidity; saturated air = 100.	A cubic foot of air—(grains of water.) Can contain at the temperature—	Does contain—	Requires for a relative humidity of 70—	60,000 cubic feet per minute require pounds of water—	Date.	Locality.
							1864.	
1	90. 5	47	14. 81	7. 06	3. 46	29. 6	June 27	Smithsonian laboratory.
2	86. 9	51	13. 50	6. 88	2. 57	27. 0	June 27	External air, Capitol portico.
3	86. 0	50	13. 15	6. 57	2. 63	22. 5	June 27	Senate chamber.
4	82. 4	77	11. 79	8. 25	Above 70	....	June 27	Senate chamber; storm.
5	84. 2	58	12. 45	7. 22	1. 49	12. 8	June 27	Senate chamber.
6	74. 3	35	9. 17	3. 21	3. 21	27. 4	June 28	Sergeant-at-arms' office.
7	77. 0	34	9. 97	2. 39	4. 59	39. 3	June 28	Senate chamber.
8	77. 0	34	9. 97	2. 39	4. 59	39. 3	June 28	Senate chamber; clear weather.
9	77. 9	32	10. 26	3. 28	3. 90	33. 4	June 28	Senate chamber.
10	77. 9	32	10. 26	3. 28	3. 90	33. 4	June 28	Smithsonian laboratory.
11	78. 8	30	10, 55	3. 17	4. 22	36. 1	June 29	Do.
12	77. 9	34	10. 03	3. 49	3. 69	31. 6	June 59	Senate chamber.
13	78. 8	36	10. 55	3. 80	3. 58	30. 7	June 29	Senate chamber; clear weather.
14	78. 8	36	10. 55	3. 80	3. 58	30. 7	June 29	Senate chamber.
15	78. 8	30	10. 55	3. 17	4. 22	36. 1	June 29	External air, Capitol portico.
16	77. 0	54	10. 00	5. 40	1. 60	13. 7	June 30	Smithsonian laboratory,
17	78. 8	48	10. 55	5. 06	2. 32	19. 9	June 30	External air, Capitol portico.
18	78. 8	48	10. 55	5. 06	2. 32	19. 9	June 30	Do.
19	78. 8	62	10. 55	6. 54	0. 84	7. 2	June 30	House of Representatives; storm.
20	78. 8	62	10. 55	6. 54	0. 84	7. 2	June 30	House of Representatives.
21	78. 8	62	10. 55	6. 54	0. 84	7. 2	June 30	Do.
22	78. 8	62	10. 55	6. 54	0 84	7. 2	June 30	Do.
23	88. 2	51	14. 04	7. 16	2. 67	22. 9	July 2	Smithsonian laboratory.
24	78. 8	80	10. 55	8. 44	Above 70	....	July 2	Smithsonian laboratory; storm.
25	84. 2	71	12. 45	8. 84	....	....	July 2	External air, Capitol portico.
26	82. 4	74	11. 79	8. 72	Above 70	....	July 2	Senate chamber.
27	84. 2	71	12. 45	8. 84	....	....	July 2	Do.
28	84. 2	71	12. 45	8. 84	....	....	July 2	Do.
29	82. 4	71	11. 79	8. 37	....	....	July 2	Do.
30	84. 2	71	12. 45	8. 84	....	....	July 2	Do.
31	84. 6	71	12. 58	8. 93	....	....	July 2	Do.

3. *Table of humidity*—Continued.

Number of experiment.	Temp. air. Fahrenheit.	Relative humidity; saturated air = 100.	A cubic foot of air—(grains of water.) Can contain at the temperature—	Does contain—	Requires for a relative humidity of 70—	60,000 cubic feet per minute require pounds of water—	Date.	Locality.
							1864.	
32	82.4	74	11.79	8.72	0.0	..	July 2	Senate chamber.
33	84.2	68	12.45	8.46	0.26	2.2	July 2	Do.
34	80.6	74	11.15	8.25	Above 70	......	July 2	Stairs ventilator to Senate gallery.
							1865.	
35	61.9	46	6.23	2.87	1.49	*12.8	Jan. 24	Senate post office.
36	70.2	32	8.04	2.57	3.05	26.1	Jan. 24	Do.
37	70.9	31	8.23	2.55	3.21	27.5	Jan. 24	Do.
38	70.5	33	8.12	2.68	3.00	25.7	Jan. 24	Do.
39	72.0	27	8.52	2.30	3.66	31.3	Jan. 24	Senate chamber gallery.
40	72.3	27	8.60	2.32	3.70	31.7	Jan. 24	Do.
41	29.8	56	1.95	1.09	0.28	2.5	Jan. 24	External air to Senate fan.
42	31.3	58	2.07	1.20	0.25	2.1	Jan. 24	External air, Capitol portico.
43	33.8	65	2.27	1.48	0.10	1.0	Feb. 8	External air, Smithsonian laboratory.
44	33.8	65	2.27	1.48	0.10	1.0	Feb. 8	Do.
45	33.8	65	2.27	1.48	0.10	1.0	Feb. 8	Do.
46	30.6	55	2.01	1.11	0.30	2.5	Feb. 9	External air to Senate fan.
47	30.6	55	2.01	1.11	0.30	2.5	Feb. 9	Do.
48	30.6	55	2.01	1.11	0.30	2.5	Feb. 9	Do.
49	70.9	20	8.23	1.65	4.11	35.2	Feb. 9	Senate chamber.
50	70.9	20	8.23	1.65	4.11	35.2	Feb. 9	Do.
51	68.0	21	7.49	1.57	3.68	31.5	Feb. 9	Do.
52	68.0	21	7.49	1.57	3.68	31.5	Feb. 9	Do.
53	64.0	27	6.58	1.78	2.83	24.3	Feb. 9	Do.
54	64.0	27	6.58	1.78	2.83	24.3	Feb. 9	Do.
55	69.8	44	7.94	3.49	2.07	17.7	Feb. 15	Room in the Smithsonian Institution
56	35.2	100	2.39	2.39	Saturat'd.	Sat.	Feb. 16	External air to the fan, House of Representatives.
57	35.2	100	2.39	2.39	Saturat'd.	Sat.	Feb. 16	Do.
58	72.7	46.5	8.71	4.05	2.05	17.5	Feb. 16	House of Representatives.
59	72.7	46.5	8.71	4.05	2.05	17.5	Feb. 16	Do.
60	70.9	46.5	8.23	3.83	1.93	16.5	Feb. 16	Do.
61	70.9	46.5	8.23	3.83	1.93	16.5	Feb. 16	Do.
62	68.4	48	7.59	3.64	1.67	14.3	Feb. 16	Do.
63	68.4	48	7.59	3.64	1.67	14.3	Feb. 16	Do.
64	65.2	57	6.84	3.90	0.89	7.6	Feb. 17	Sleeping apartment, afternoon.
65	68.4	46	7.59	3.59	1.72	14.7	Feb. 18	Sleeping apartment next morning.
66	37.4	67	2.60	1.74	0.08	0.7	Feb. 24	External air to Senate fan.
67	37.4	67	2.60	1.74	0.08	0.7	Feb. 24	Do.
68	37.4	67	2.60	1.74	0.08	0.7	Feb. 24	Do.
69	66.9	31	7.23	2.24	2.82	25.6	Feb. 24	Senate chamber.
70	66.9	31	7.23	2.24	2.82	25.6	Feb. 24	Do.
71	70.9	28	8.23	2.30	3.46	29.7	Feb. 24	Do.
72	72.3	28.5	8.65	2.45	3.57	30.6	Feb. 24	Do.
73	72.3	28.5	8.65	2.45	3.57	30.6	Feb. 24	Do.
74	36.7	93	2.53	2.35	Above 70	....	Feb. 25	External air to the fan, House of Representatives.
75	69.0	43	7.74	3.33	2.09	17.9	Feb. 25	Hall of Representatives.
76	69.0	43	7.74	3.33	2.09	17.9	Feb. 25	Do.
77	69.8	41	7.94	3.26	2.30	19.7	Feb. 25	Do.
78	69.8	41	7.94	3.26	2.30	19.7	Feb. 25	Do.
79	51.4	49	4.29	2.10	0.90	7.7	Feb. 27	External air to the fan, House of Representatives.
80	71.6	37	8.41	3.11	2.78	23.8	Feb. 27	Hall of Representatives.
81	71.6	35	8.41	2.94	2.94	25.2	Feb. 27	Do.
82	71.6	35	8.41	2.94	2.94	25.2	Feb. 27	Do.
83	71.6	35	8.41	2.94	2.94	25.2	Feb. 27	Do.
84	64.2	34	6.62	2.25	2.38	20.4	Mar. 28	External air, top of dome.
85	64.2	34	6.62	2.25	2.38	20.4	Mar. 28	Do.
86	65.0	35	6.80	2.38	2.38	20.4	Mar. 28	External air at the ground.
87	68.0	60	7.49	4.49	0.75	6.4	Mar. 31	Public schools,
88	68.0	60	7.49	4.49	0.75	6.4	Mar. 31	Public schools,
89	68.0	60	7.49	4.49	0.75	6.4	Mar. 31	Public schools, Temp. of external
90	74.0	63	9.08	5.72	0.64	5.5	Mar. 31	Public schools, air 59°, rel. h. 72.
91	75.0	60	9.67	5.80	0.97	8.3	Mar. 31	Public schools,
92	75.0	44	9.67	6.19	0.58	5.0	Mar. 31	Public schools,

* That is, for air of a temperature of 29°.8 Fahrenheit, or a temperature of 70°, the air would require more in proportion to its expansion.

† The ventilation for the Senate is 30,000 cubic feet of air per minute.

II. EXPERIMENTS UPON THE HUMIDITY OF THE CAPITOL EXTENSION

Embrace a series of ninety-two observations made in the summer and in the winter. Those of the summer, Nos. 1 to 34, inclusive, illustrate admirably the condition of the air furnished by the ventilating apparatus at that season.

The summer experiments.—On June 27, 1854, after a prolonged dry period, the temperature of the air at an open window of the Smithsonian laboratory, at noon, was 90°.5 Fahrenheit. At 2 p. m. a storm was approaching, and the air had a temperature of 86°.9. The relative humidity had increased from 47 to 51. During the experiments in the Senate chamber the storm burst upon us, but was of short duration. The relative humidity in the chamber rose, and the temperature fell with the storm; the former was at its maximum (Ex. 4) at 77, and the temperature reached its minimum at 82°.4. At the commencement of the observations it would have taken twenty-seven pounds of water per minute to have given to the air of the Senate chamber the maximum relative humidity for comfort, viz. 70. The necessity for water was entirely obviated at the time of Experiment No. 4, and when the examination was completed the humidity was within the mean amount for health. I watched the condition of the Senators while the relative humidity was increasing, and although it was not very low in the commencement, as it had been gradually increasing all the morning, I could not fail to observe their expressions of relief and comfort (in which I shared) at the changed hygrometric state of the atmosphere, the temperature having at the same time fallen 3°.6 Fahrenheit.

On July 2 (Ex. 23–34) there was another storm which commenced before I reached the Senate. Before the storm the temperature of the air at a window of the laboratory was 88°.2, its relative humidity 51. As the storm was ceasing, at the same place, the temperature was 78°.8, the relative humidity 80. At 3 p. m. the external air at the Capitol was 84°.2, and the relative humidity 71. The temperature and humidity were the same in the chamber as in the external air; but at the registers, through which the fresh air entered the Senate chamber, the temperature was slightly lower, and the humidity a little higher.* This air was very comfortable.

On June 30 (Ex. 16–22) the air of the Representatives' hall was examined under the disturbing influence of a storm, which gave a sufficient relative humidity to the atmosphere.

On June 28 and 29 (Ex. 6–15) the air of the Senate chamber was examined during clear weather, the temperature of the air being high, but not excessive for summer. The temperature and humidity in the chamber and in the external air were nearly alike, and the humidity was very low.

A jet of water in one of the air-ducts during these summer observations cooled the air in the duct from one to two degrees, but did not suffice to lower the temperature of the apartment below that of the external air.

It will be observed from Table 1 that the mean relative humidity at Washington at 2 p. m., for 5 years, in June, is 57.4, and that the minimum has fallen as low as 22. The summer experiments show that the air of the legislative halls may be made cooler and more pleasantly moist in the summer by the judicious and *sufficient* evaporation of water. It must be sufficient to produce the desired effect. It must be employed with judgment, and *not added* when the air has a high relative humidity, for in such a case it would communicate too much moisture, and might even introduce a portion in the form of mist, to be deposited upon the walls. For example, with the temperature (Ex. 1) at 90°.5, the evaporation of twenty-nine pounds of water per minute would raise the humidity to its healthful maximum *at that temperature*; so much, indeed, would not be needed, for this evaporation would occasion a fall of the temperature several degrees.

It is evident that the evaporation of any more water at the time of Experiment 4 would be hurtful. To add water, whether in winter or summer, requires *intelligent and watchful industry*, aided by a proper psychrometer. Fortunately the latter desideratum has been supplied by an invention of Mr. William Edson, who has contrived a hygrometer which gives at any time the dew-point and relative humidity by a mechanical arrangement, obviating a recourse to tables or calculations.

An objection has been made to the heating action in summer of the terrace from which the air is drawn. The experiments have not given any indication of such heating action, nor was it to be expected. The warm pavement radiates its heat into space, and does not raise the temperature of the air upon it to any considerable extent. This may be *seen* by looking over a similar heated surface toward the sky. The hot air may be perceived by its tremulous motion, which arises from the different refrangibility for the rays of light of the unequally heated strata of air. It will be noticed that this elevation of temperature does not extend more than a few feet above the ground. I have not found the terrace, nor the short vertical shafts by which the air enters the fan-room, in a clean condition. They ought to be maintained scrupulously neat, and in the summer time should be washed off with the hose at least once daily.

* There was a small jet of water in the air-duct.

The winter experiments are very interesting, and indicate the cause of the complaints which some have made as to the ventilation. They demonstrate that the difficulty lies in a deficiency of moisture in the air. The "*absolute*" dryness of the air in winter is great, and its "*relative*" dryness is vastly increased after it has been raised to the temperature requisite for heating the halls. It will not be necessary to take up the results *seriatim* to prove this. A glance at the table will show how low the degree of relative humidity is. Even when, as in Ex. 56–61, the relative humidity of the external air is 100, that of the halls is below the healthy minimum; and at times the moisture falls to 20. The mean relative humidity at 2 p. m., for the external air of the five Januaries of Table 1, is 67.

The remedy for this defect consists in adding to the air of the halls from sixteen to thirty-five pounds of water per minute for a ventilation of 60,000 cubic feet of air per minute.

This moisture must, as was said for the summer experiments, be added intelligently. Too much water would be as injurious as too little.

A sufficiency of moisture would enable a somewhat lower temperature to be maintained in the halls. The moisture might be added by the cautious injection of steam. A commission of scientific men (Peclet's nouveaux documens) proposed to maintain the air of the Hospital du Nord at a relative humidity of 50 by the addition of steam. Some of the heating coils in the Capitol extension were originally provided with steam-cocks for the same purpose. I think that the rapidity of the current in the present air-ducts would render a sufficient hydration of the air, without carrying the water into the halls in the form of mist, impossible. To effect this object, therefore, would require a much larger chamber in which the air-current could pass with diminished velocity and be mingled with steam* in the winter time, and with water in the summer. The jet of water in the air duct, in the experiments of last summer, was insufficient and did not cause a perceptible increase of the relative humidity of the halls.

The following experiment, performed on February 23 to 27, gave a similar result:

An iron pan, of 60 square feet in surface, was filled with water and placed in the (heated) main air-duct of the House of Representatives. The water was warmed by steam-pipes. With an average steam pressure of 24 pounds, and a temperature of the water equal to 172° Fahrenheit, 74.8 gallons of water were evaporated in five hours, which is equal to 14.96 gallons† per hour and 0.25 gallon = 2.08 pounds per minute. The moisture in the hall was determined upon February 25, with the evaporator in action, and again upon February 27, the heat having been excluded from the evaporator from the afternoon of February 25. As, by an oversight, the *water* remained in the tank, the experiment was less decided than it would otherwise have been, since the current of dry, warm air must have taken up water in the experiment of February 27.

To ascertain the effect of this evaporation it will be necessary to calculate the amount of water which the air of the halls receives from the atmosphere and from other sources.

In this calculation I have neglected the barometric pressure, which did not vary much from its normal, and also the change of volume of the air due to the tension of aqueous vapor, which will not influence the results materially.

I have used $\frac{1}{460}$ as the expansion of air per Fah. degree from 0° Fah. In Experiments 46 and 49 a cubic foot of the external air contains 1.11 grains of water at 30°.6 Fah., and by expanding to 70.9° (the temperature of the Senate chamber) a cubic foot would contain 1.03 grains of moisture; but the air of the Senate contains 1.65 grains; hence 0.62 grains of water have been added to it by the breath of the audience, by the absorption of water from the ground through the air-duct, and from other sources. Since a thousand men would exhale 12,000 grains of water per minute, they would introduce into the 60,000 cubic feet of air furnished by the fan per minute 0.2 grains of moisture per foot, which leaves 0.42 grains to be attributed to other sources than the exhalation of the audience.

In Experiments 74 and 75, upon the moisture of the external and internal air at the House of Representatives, with the evaporator in action, out of the 3.33 grains of water per cubic foot of air of the hall, 2.21 are present from the external air and 1.12 grains have been added from other sources. If the same conditions exist as in Experiments 46 and 49, 0.62 grains of water have been furnished by the breath, &c., and 0.5 grains by the action of the evaporator.

In Experiments 79 and 80, in the House of Representatives, the evaporators being filled with *cold* water, in a cubic foot of air, out of the 3.11 grains of water present, 2.02 are due to the moisture of the external air and 1.09 grains to the action of the hot air over the water, to the breath, and to other sources; hence 1.09 — 0.62 = 0.47 are due to the *cold* evaporator. The difference between these two experiments is 0.03 grains of water per cubic foot. If we compare the experiments of the House of Representatives alone we have for the evaporator, with heat, 1.12 grains; without heat, 1.09 grains;

* *Vide* Autozone, p. 92.

† According to the observation of the engineer, Mr. Jacob D. Forney.

difference, 0.04 grains per cubic foot of air. As the influence of *heat* upon the evaporation of water in the tank is very considerable, it appears that the benefit to the hydration from the evaporator is very small.

For a ventilation of 60,000 cubic feet per minute, in Experiment 49 in the Senate, 35.2 pounds of water per minute are required to effect a relative humidity of 70, or half that quantity for a ventilation of 30,000 cubic feet.

In Experiments 75 and 80, in the House of Representatives, this quantity of water amounted to 17.9 pounds with the active evaporator, and to 23.8 pounds without it.

It is certain that the hydration of the air will involve, in the winter, a considerable expenditure of fuel for a powerful ventilation; but the hydration is as necessary to health and comfort as the warmth.

The following is an approximate calculation of the amount of coal needed to yield to the air of the Senate a relative humidity of 70, based upon the data of Experiments 51 and 52:

Mr. Joseph Nason (Ex. Doc. No. 20, 36th Cong., 1st session, p. 10) estimates, upon the assumption that 1 pound of coal will evaporate 7½ pounds of water, that 7.33 tons of coal will be required per day, of 24 hours, to produce an agreeable temperature in the hall of Representatives, with a ventilation of 50,000 cubic feet of air per minute. In the Senate, for a ventilation of 30,000 cubic feet, according to the same calculation, 4.06 tons of coal would be required for 24 hours. By Experiment 51, 31.5 pounds of water per minute would be needed to communicate a relative moisture of 70 to 60,000 cubic feet of air per minute, or 15.75 pounds for a ventilation of 30,000 cubic feet. This quantity of water would require 2.1 pounds of coal per minute, or 1.35 ton per 24 hours. But the air required 4.06 tons for heating it, which numbers are in the proportion of 1 to 3.

The best ventilation and hydration cannot suit every individual. In an audience some will need more moisture, and some less heat, than others, and a mean, adapted to the wants of the majority, must be maintained. It is somewhat with warming and ventilation as with civilized society—a portion of individual comfort must be resigned to secure the benefits of civilization to the community.

V. MISCELLANEOUS SUBSTANCES IN THE ATMOSPHERE.

In addition to the principal constituents of the atmosphere which have been treated in this report, there are others which exist in minute proportion, but which, doubtless, have a decided influence upon health.

Mülder observed that a flame of hydrogen gas, burning in breath from the lungs, did not exhibit in the spectroscope the reaction of sodium, although the air, before breathing, gave the same in a decided manner; and he infers that the lungs act as a filter for the small quantity of chloride of sodium floating in the air. May not other solids or gases, supposed to be innocuous, be thus absorbed to the detriment of our health? The following is a brief account of some of these constituents of the atmosphere:

I. AMMONIA.

Ammonia is always contained, in small proportion, in the air, and has been supposed by Liebig and others to perform an important function in vegetation.

Horsford, (Am. Asso. for Advancement of Science, 1849, p. 124,) in an examination of the atmosphere for this constituent, obtained, as a result of experiments, from 1.2 to 47.6 parts of ammonia in one million parts of air, the alkali being in larger proportion in July and least in December. No difference in the amount was detected in the air collected on the sea-coast during an east wind compared with the air of a densely-populated locality in Boston.

Pierre (Liebig and Kopp, Jahresbricht v. p. 356) gives, as the result of four months' observation in the winter at Caen, 3½ millionths of ammonia, by weight, in the atmosphere. The same chemist, by a subsequent (Comptes Rendus, xxxvi, 694) examination of the air for nine months, at the same locality, found ½ of a millionth part of ammonia.

Bineau, (Ann. de Ch. et de Phys., [3] xlii, 462,) in a series of experiments performed at Lyons and at Caluire, in the neighborhood, during 1852–'3, found that at the former place the mean annual amount of ammonia in the air was between ¼ and ⅕ of a millionth, while in Caluire it was in winter 40 and in the summer 80 billionths in weight.

The following proportion by volume of ammonia in one million *volumes* of air have been given by different observers: Graeger investigated the air of Alsace; Kemp, that of Ireland, during two summer days, at an elevation of 300 feet above the sea level; and Fresenius at Wiesbaden, Germany, during forty days of changeable weather.

Table of volumes of ammonia in one million volumes of air.

Observer.	Ammonia, NH_3.	Oxide of ammonium, NH_4O.	Carbonate of ammonia. $NH_4O\ CO_2$.
Graeger	0.333	0.508	0.938
Kemp	3.880	5.610	10.370
Fresenius, day	0.098	0.153	0.283
Fresenius, night	0.169	0.257	0.474
Fresenius, mean	0.133	0.205	0.379

The ammonia in the first column is *equivalent* to so much oxide of ammonium and carbonate of ammonia as stated in the second and third columns.

II. ACIDS IN THE AIR.

Dr. R. Angus Smith (Qr. Jour. Chemical Society, xi, p. 209) observed at the sea side (Blackpool) a slight degree of acidity in the air, since blue litmus paper had its color somewhat diminished by exposure over night to the air; but in Manchester the reagent became red in half an hour, and sometimes in ten minutes.

The same chemist examined the smoke from chimneys, and found in 100 cubic feet (reduced to 65° Fahrenheit) the following amount of acid in grains:

Specimens of smoke.	Sulphurous acid.	Equivalent to hydrate of sulphuric acid.
1	16.260	24.050
2	23.850	36.522
3	5.322	8.150
4	5.271	8.072
Mean	12.651	19.199

From a determination of the sulphur in coal, and from the analysis of rain for its acid, Dr. Smith makes the following calculations:

Sulphur, equal to one per cent. of the coal burned in Manchester, would give an amount of 61,245 tons of sulphuric acid per year. Over an area of 16 miles, and with a rain-fall three feet deep, one thousand tons of sulphuric acid fall with the rain in a year, which is only about 1.588 per cent. of the quantity produced. Dr. Thompson always found in the air of London sufficient sulphuric acid to give an acid reaction to water through which it was passed. These acids (sulphurous and sulphuric) are always found in the air of towns where coal is burned, and are not considered injurious, but rather beneficial, as tending to arrest putrefaction.*

III. ORGANIC MATTER IN THE AIR.

Dr. Thompson (Appendix to Report of the Committee for Scientific Inquiry in Relation to the Cholera Epidemic of 1854, p. 110, London) appears to have first recognized the importance of organic matter as a constituent of the air of towns. He found that the air of London, when passed through oil of vitriol, communicated a dark tinge to it, and if large quantities of air were passed through distilled water the inevitable result was the formation of fungi.

Dr. R. Angus Smith (Op. Cit., p. 217) tested the air for organic matter by ascertaining the amount of air necessary to discharge the color of a solution of permanganate of potash, of which the strength was obtained by decomposing a known weight of sugar or of oxalic acid. Supposing the sugar and the organic matter in the air to be decomposed by exactly the same amount of permanganate, which will not involve a great error, he obtained the proportion of organic matter existing in the air.

* Thompson.

The following table of his results is taken from the Chemical Gazette of 1859, p. 176:

	Grains of organic matter in 100 cubic inches of air.
Manchester, 131 experiments	52.9
Manchester, All Saints, east wind, 37 experiments	52.4
Manchester, All Saints, west wind, less smoky	49.1
Manchester, All Saints, east wind, 16 experiments, above 70° Fahrenheit	58.4
Manchester, All Saints, east wind, 21 experiments, below 70°	48.0
Manchester, in a house kept rather close	60.7
In a pig-sty, uncovered	109.7
Thames, at city, after warmest weather of 1858—no odor perceived	58.4
Thames, Lambeth	43.2
Thames, Waterloo bridge	43.2
London, 6 experiments during warm weather	29.2
In the fields south of Manchester	13.7
In the fields north of Highgate—wind from London	12.3
North Italy—warm weather in the fields	6.6
Near Milan—moist fields	18.1
London, after a thunder-storm	12.3
German Ocean—calm, 60 miles from Yarmouth	3.3
Hospice Mt. St. Bernard—fog	2.8
North Lancashire	2.8
Forest at Chamounix	2.8
Lake Lucerne	1.4

Hoffmann proposes the use of the permanganate of potassa for the purification of the air. Dr. Smith, repeating the experiment of passing ozonized air through blood, confirmed the fact of a decided and remarkable reddening. He thought that he could employ this reaction for determining the comparative proportion of ozone in the air of the sea-coast and in that of Manchester, but found that in the latter place, where the ozone was *less*, the reddening reaction was *much more decided*. Here is a visible effect upon the blood produced by the air of towns, the cause of which is unknown, and which may, operating constantly, act injuriously, and thus account for the superior healthfulness of the country.

IV. MICROSCOPISMS AND GERMS IN THE AIR.

Pasteur (Comptes Rendus, l, 303, 849, and li, 348) filtered air through gun-cotton, and after having dissolved the same by alcohol and ether, examined the insoluble remains. He supposes that germs of infusoria are present in all air, and are the cause of fermentation and putrefaction. H. Hoffman and Van der Broeck (Ann. der Ch. und Pharmacie, cxv, pp. 75 and 288) drew the same inference from their experiments. Schroeder and Dench, (Id., cix, 35,) and Schroeder, (Id., cxvii, 273,) confirm these views by their results. They found that almost all organic substances, even those of ready putrefaction, such as blood, fibrine, albumen, caseine, sugar, starch, &c., were preserved unaltered when heated to the boiling point in a bottle which was immediately stopped by a loose plug of raw cotton, so that, on cooling, the air entering the bottle would be filtered through the cotton and be deprived of solid substances floating therein. They attribute putrefaction and fermentation to the germs of animalcules suspended in the air; a peculiar kind being required for each kind of fermentation. Schroeder found that these germs were destroyed by a heat of 212° Fahrenheit; but that milk, meat, and yolk of egg contain such as require a very prolonged heat at that temperature, or a higher temperature, viz, that of water boiling under pressure, for their destruction.

By the heretofore received theory of Leibig and others, fermentation is a decomposition incited and maintained by a "ferment," or readily oxidizable body. The motion of the atoms in the decomposing ferment is imparted to the atoms of the fermentable body, causing it to fall asunder into less complex compounds. The germ theory has not yet been accepted definitely; experiments and discussions concerning it are in progress, for which consult Pasteur, Pouchet, Berthelot, Schroeder, Boussingault, Karsten, in the Comptes Rendus, Jour. Pr. Ch., &c., *passim*.

Berthelot (Jr. Pr. Ch., lxxxv, 465, and Comptes Rendus) found that in the alcoholic fermentation of 100 parts of sugar, from 95 to 96 per cent. yielded alcohol, the formation of which could be explained by the "ferment" theory; but the remaining 4 or 5 per cent. of sugar formed from 3.2 to 3.6 of glycerine; from 1.2 to 1.5 of cellulose; from 0.6 to 0.7 of succinic acid, and from 0.6 to 0.7 of carbonic acid, together with fat and other undetermined products. It follows from this that the evolution of carbonic acid is not in an exact equivalent proportion to either the sugar or the alcohol. Pasteur found in the experiments before alluded to of filtering air through gun-cotton, dissolving the latter and examining the residue by the microscope, that it contained starch granules and undefined globules, which seemed to him to be spores. When this residue was

brought into sugar-water, certain known animalculae and infusoria were developed. The same results were obtained, using asbestos for the air filter, and they were absent when the asbestos had been first ignited, and then exposed to the current of air from which the germs were removed before reaching the mineral. He experimented upon air from different localities with a view of ascertaining the relative proportion of germs capable of producing fermentation. For this purpose he prepared a number of glass matrasses containing fermentescible liquids, hermetically sealed at the boiling temperature. When these were opened in any place a certain quantity of air would rush in, together with whatever germs might be present. The flasks were immediately resealed and put aside, when the presence of the germs would soon be manifested by the phenomenon of fermentation, accompanied by the presence of infusoria.

Of 20 specimens of air in each of the three following series—

1st. In the country, near the ground, 8 contained germs.

2d. Upon the first plateau of the Jura Mountains, 2,600 feet elevation, 5 contained germs.

3d. Upon Montanvert, 6,000 feet high, 1 contained germs.

In the cellar of the Paris Observatory, using precautions against disturbing the ground, no air causing fermentation was found; it was as free from that property as air which had been heated.

All specimens of fresh milk coagulate in from three to ten days, and contain chiefly *vibriones*. If, however, milk be boiled for a prolonged period, and heated air, deprived of its germs, be suffered to enter the vessel, it does not ferment. The oxygen of the air attacks the fat, which becomes lumpy and tallowy; (see Wetherill on Adipocire, Transactions Am. Phil. Soc., vol. xi;) but the albumen from which, according to the former theory, a ferment is generated, remains unaltered. The spores of the mucidineæ retain their fermentative power at a temperature of 248° Fahrenheit, but are killed by a half an hour's exposure to a temperature of 255° Fahrenheit. In water, however, they lose their vitality at the ordinary boiling temperature.

Karsten (Liebig and Kopp, Jahresbericht, 1862, p. 106.) discovered an oxidizing power in the air which he deems of value in relation to the question of atmospheric miasms. He found that dry, non-nitrogenized bodies such as sugar, starch, gum, wax, rosin, caoutchouc, cork, &c., are slowly oxidized in the air at ordinary temperatures, with the formation of carbonic acid and water. When the oxygen is not present in excess, the additional products of decay (rottenness) arise. After depriving air of carbonic acid, he passed 60 liters of it, in single bubbles, through a series of vessels, (in which all joints of cork and caoutchouc were avoided,) filled alternately with air free from carbonic acid, and with lime water, and thus always found a precipitate of carbonate of lime, which he attributes to an oxidation of organic matter in the air. He believes that in Elliot and Storer's observations on the difficulty of depriving air of carbonic acid the presence of this gas arose from the oxidation of the joints of cork and caoutchouc; for when air is first passed through a tube containing red-hot oxide of copper, by which its organic matter is burned, and then freed from carbonic acid by caustic potash, no precipitate in the lime-water announces the presence of carbonic acid. By this oxydizing action of the air, due probably to ozone, a self-purification of the atmosphere is constantly taking place.

V. DUST SUSPENDED IN THE AIR.

Pouchet (Comptes Rendus, xlviii, 546) made an extensive microscopic examination of the dust deposited from the air in different places. Some of it had accumulated for ages; as in the ruins of Thebes; in the tomb of Rameses II; in the sepulchral chamber of the great pyramid; in the temple of Venus Athos, at Phile; in the temple of Serapis; at Pouzzoles; in the head of a mummied dog from the pits of Beni-Hassan, and in the cabinet of a Jewish antiquary, at Cairo. Some of the dust of less ancient buildings was also examined, viz, of the tower of St Georges d'Amboise, at Rouen; interior of the Abbey Fecamp; laboratory of the Museum of Natural History, at Rouen, and other places. From the results of thousands of such observations substances were detected by the microscope, consisting, 1st, of mineral origin, being the detritus of the rocks of the locality; 2d, of animal nature, as the dried remains of small infusoria of different kinds; fragments of the antennæ of coleoptera; scales from the wings of nocturnal and diurnal butterflies; hairs of different animals, some of them died red, blue, or green, and derived from clothing; hair of rabbits and bats; epithelial scales; spiders' web, &c.; 3d, of vegetable origin, consisting of fragments of the tissue of various plants, the ligneous fiber in small quantity, but the fragments of cells and vessels being of greater frequency; many vegetable hairs or filaments; pollen; cryptogamic spores; many filaments of cotton, for the most part colorless, but sometimes dyed and proceeding from clothing.

Finally, wherever M. Pouchet's observations extended, whether of ancient or modern dust, the presence of *starch*, of different plants, but especially of wheat, was nearly always demonstrated. The larger starch granules were rare; those detected were of

ovoidal or spherical shape, measuring from 0.014 to 0.028 millimeter in diameter, but more frequently of the latter dimension. The ancient starch polarized light and had all of the physical and chemical properties of recent starch; some of it was of a violet tint, as if by the action of iodine. On the summits of mountains and on other elevated places starch was rarely or not at all detected. Pouchet *compared* the air of different localities by collecting and examining microscopically the solid matters floating in the volume of one cubic decimeter of the air, and found the air of towns loaded with a vast quantity of organic *débris*, and of objects employed in civilized life. In the marsh-lands and on the plains he found an excess of vegetable particles. In the open sea, far from the shore, and on the mountains, above the zone of habitations, he found, even in a volume of ten cubic decimeters, the atmospheric corpuscules to be very sparse. At sea, however, between Sardinia and Sicily, in the middle of the Ionian sea, or upon the summit of Etna, a cubic decimeter of air always exhibited "immense legions" of ciliated infusoria.

VI. MICROSCOPIC EXAMINATION OF THE AIR OF THE CAPITOL.

On February 20, 1865, glass microscope slides were hung from the ventilating apertures in the House of Representatives, so that they remained suspended horizontally six inches below the ceiling. Two slides, tied back to back, were coated with glycerine and placed at the east end, and two similar ones at the west end of the ceiling. The position of the slides was such that on two dust could fall or settle gradually, and against the remaining two the dust would rise vertically. On March 8 of the same year the slides were examined. No difference was observed between the slides from the east and west end of the ceiling.

Those upon which the dust had settled were coated very perceptibly by it. Examined by the microscope it proved to be principally fine quartzy and earthy matter arising from the streets, the former exhibiting its characteristic colors in polarized light; there were also animal hairs, some of them dyed, (fibers from the carpet,) and epithelial scales from the mouth, starch granules, &c.

Very little matter was deposited upon the slides containing glycerine upon their inferior surface. The objects detected by the microscope were epithelial scales from the mouth, and starch granules, which exhibited beatifully the black cross by polarized light. Nothing having the appearance of spores was detected in these examinations.

VI. OZONE.

An examination of air for the purposes of ventilation would scarcely be complete without allusion to ozone—a body which has engaged the attention of chemists for the past twenty-five years, but of the true nature of which, notwithstanding the labor of research bestowed upon it, we know so little.

I. NATURE OF OZONE.

The air surrounding the electral machine when in action, and air confined with moist phosphorus, has a peculiar penetrating odor, and exerts a decomposing action upon the iodide of potassium.

These two cases have been referred to one cause—viz, the production of ozone, which is supposed by some to be an allotropic modification of oxygen, analogous to what has been observed in sulphur, phosphorus, carbon, and some other bodies, while others assign for the rationale of the phenomenon a decomposition of ordinary oxygen into its hypothetical constituents, $+0$ and -0. Ozone is the most active oxydant known: it acts energetically by mere contact at the ordinary temperature, carrying bodies to the highest degree of oxidation of which they are capable. Thus silver is converted into the peroxide; phosphorus into phosphoric acid; arsenic into arsenic acid; sulphur, sulphurous acid, and sulphuretted hydrogen, into sulphuric acid; lead and litharge into the peroxide; protoxide of manganese into the peroxide; sulphide of lead into the sulphate; ammonia into nitrate of ammonia, &c.

It also oxidizes many organic bodies; when breathed in sufficient quantities, excites powerfully the organs of respiration, producing cough, and speedily killing smaller animals.

Fortunately it cannot be present in atmospheric air in large quantity: $\frac{1}{1300}$ of this body being the largest proportion with which we have been able to load the air. Substances upon which ozone acts withdraw it from the air.

Andrews and Tait (Phil. Trans., 1860, 113) found that oxygen through which quiet electric discharges were effected experienced a diminution in volume of $\frac{1}{12}$; that when left to itself, at ordinary temperatures, it expanded again very slowly; at 212° Fahrenheit it expanded more rapidly; at 518° Fahrenheit it regained its original volume, and lost all ozone reaction. This, then, is the temperature at which ozone is completely *destroyed*.

The presence of ozone is indicated by its action on paper imbued with the tincture of gum guiacum, which it turns blue, or with paper dipped in a mixture of water and starch, with [illegible] of its weight of iodide of potassium and dried. The ozone liberates the iodine, which acts upon the starch, producing the characteristic blue color of the iodide of starch.

Certain bodies which have been called "ozone carriers" possess the peculiar property of absorbing ozone, and yielding it to other bodies upon which it is capable of acting.

Oil of turpentine,* under the influence of light, plantinum black or sponge, and the *blood corpuscules*, possess this property, so important in its physiological relations. Schoenbein found that air containing [illegible] of ozone smelled sensibly of it, and is of the opinion that there exists a connection between the amount of ozone in the atmosphere and catarrhal affections. Gorup v Besanez (Ann. der Ch. und Pharmacie, cxxv, 207) acted upon a variety of organic substances by ozone, and studied their products of oxidation. He found that, in the presence of carbonate of soda, grape and cane sugar (the latter, with greater difficulty) were perfectly oxidized by ozone, carbonic and formic acids being the sole products. The volatile fatty acids are also perfectly oxidized, while the fixed ones, such as palmitic and stearic, are acted upon with difficulty. The fats alone are not readily attacked, but in presence of an alkali they are quickly decomposed, the ozone acting upon the glycerine. This author draws important deductions from the action of ozone on organic bodies in his Lehrbuch der Chemie, vol. iii, *passim*.

Contradictory conclusions have been drawn with reference to the relation of the atmospheric ozone to health and disease. Mr. Smallwood, in a long series of experiments upon the ozone of the atmosphere in Canada during the prevalence of the cholera and at other times, favored the idea of a deficiency of ozone during the epidemic.

During the Crimean war the surgeons of the French army established the facts that—

1. The more the ozone reagent papers were colored in the air the more numerous were the sick who were taken to each of the hospitals.
2. The higher the temperature, there were *fewer* entries of sick and fewer deaths.
3. At the three observatories the ozone curve was essentially the same; and
4. The curve for the temperature was also the same.
5. At observatory No. 1 the less the ozone the greater was the number of deaths; while at observatory No. 2 it was the reverse.

Dr. Moffat (Rep. British Association, 1851) concludes, from a large number of observations, that the ozone in the atmosphere plays an important part in controlling or permitting epidemics, which it effects by removing the poison from the air. During the prevalence of the cholera at Newcastle, in 1853, the ozone was at its minimum. From August 24 to September 11, 1854, ozone was only once perceived, and then in a minimum quantity. The cholera was then at its height in London. Dr. Moffat states that, on the 10th of September, with a south wind, the ozone increased and the cholera cases diminished.

Bineau (Ann. de Ch. et de Phys., [3] xlii, 462) detected ozone but seldom in the air of Lyons, although he observed it always in the air of the neighboring country. He attributes the deficiency in the city to the action of organic substances in the air.

Pless and Pierre (Wien. Acad. Bericht, xxii, 211) discovered 0.02 milligram of ozone in 255 liters of air.

Zenger (Id., xxiv, 78) found, from 12 experiments, from 0.002 to 0.01 milligram in 100 liters of air.

R Angus Smith (Qr. Jour. Ch. Soc., xi, 196) found that the air of Manchester did not react with ozonoscopic paper, nor was there any reaction in the country when the air came from the city, which he attributes to the absorption of ozone by the products of combustion arising from the large amount of coal consumed in the city.

C. Kosmann (Comptes-Rendus, lv, 731) ascertained that in Strasburg, and at a short distance therefrom, there was more ozone in the air of the country than in that of the city. In the city the maximum of ozone was in the day time; in the country it occurred in the night. He found also, by the action upon Schoenbein's test paper, that the green portions of all plants exhaled ozone.

Mr. Carey Lea (Am. Jour. Sci.) discovered that the growth of plants is retarded in an atmosphere strongly impregnated with ozone.

A. Poey (Comptes-Rendus, lvii, 344) found that, in the city of Havana, the ozone reaction diminished with the elevation, while in the country it increased. He found also that the atmospheric moisture influenced the amount of ozone.

J. Boehm (Bericht Acad., Wien, xxix, 409) has given the results of four years' regular observations upon the ozone of the atmosphere made in the city and environs of Prague.

The observations were made with ozonoscopic paper exposed to the atmosphere, observed and changed at 7 a. m. and 7 p. m.; the proportion of ozone being determined by the depth of shade of the color produced.

*Schoenbein saturated oil of turpentine with ozone to a degree that it had double the bleaching power of good hypochlorite of lime. (bleaching powder.)

Boehm obtained different results with paper prepared from the same formula by different persons, and claims but general conclusions from his observations. He has tabulated his results, and has illustrated them from January, 1857, to March, 1858, by a series of curves representing the relative humidity, rain, snow, or fog, clouded proportion of sky, strength and direction of the winds, and ozone.

From a consideration of these curves it is seen that the ozone bears no relation to the relative humidity, rain or thunder storms, clouds, &c., but is intimately connected with the force and direction of the wind, which was generally from the west, when the phenomenon of ozone was perceived.

Boehm attributes his effect to the position of the observatory in the city of Prague; the easterly winds passing over a portion of that town, which is thickly settled and crowded with factories, the emanations of which deprive the air of its ozone.

In the country and in the suburbs the presence of ozone was found to be constant. The author, without expressing a decided opinion on the relations existing between the presence of ozone in the atmosphere and health, calls attention to the fact that, in Kœnigstadt, a place not particularly noted for salubrity, he obtained as decided reactions of ozone upon the healthiest mountains, and that the coloration of the test paper is more decided in Vienna, a city noted for its lung and typhoid fevers, than in Prague, which is ranked justly with the healthiest of towns.

M. Hozeau, of Rouen, inferred, from a series of observations which extended over four years, that the atmospheric ozone is least in February, begins to increase in March, and reaches its maximum in May and June, after which month it diminishes to its minimum in February.

Dr. W. B. Rogers (Am. Assoc., Albany meeting) observed that the action of the city of Boston deprived air passing over it of its ozone.

II. EXPERIMENTS ON OZONE IN WASHINGTON.

The following experiment was performed to ascertain whether the ozonoscopic test might not be increased in delicacy. Some test paper was prepared according to the following formula of Osann: thirty-two grains of starch were rubbed in a mortar with the same amount of cold water; four ounces of water, in which three grains of iodide of potassium were dissolved, were boiled and mixed well with the starch: the whole was boiled again, cooled, and placed in a stoppered bottle. When test paper was needed the bottle was shaken, slips of Swedish filtering paper were dipped in the liquid and dried. This paper was instantly colored of a deep shade when dipped in a bottle of air ozonized by phosphorus. When exposed over night to the external air, at the Smithsonian Institution, the ozone reaction was very decided.

At 3*h*. 30*m*. March 6th, twenty-four liters (6¼ gallons) of air were drawn, by an aspirator, from a hole in a south window of the Smithsonian laboratory: the air being from the south and consequently not passing over the densely populated quarter of the city. The air traversed a drawn-out glass tube and impinged upon a slip of the test-paper contained in a Woulfe's bottle, which was covered with black paper to prevent the bleaching action of the light upon the iodide of starch. The current of air was drawn slowly, so that two and a half hours were needed to aspirate twenty-four liters. The experiment was repeated twice on different days, once keeping the test-paper moist. It was impossible to detect the slightest reaction of ozone. On the night of March 8th ozone reagent papers were exposed to the external air outside of a window of the Smithsonian laboratory, and in a similar position at a dwelling on F street north, between 11th and 12th streets west, in a populous locality of Washington. The papers of the latter position did not give any indication of ozone, but those at the laboratory, exposed to the air of the Smithsonian park, evinced a decided ozone reaction. Hence the air of the public grounds contains ozone when that of the crowded city does not. This experiment was repeated several times with similar results.

III. THE RELATION OF THE VENTILATION OF THE CAPITOL TO OZONE.

The air entering the fans at the Capitol was found by the test-papers to contain ozone, differing in this respect from the crowded city.

On February 28th, at 12*h*. 45*m*. p. m., slips of ozone reagent paper were placed in the current of air entering the fan of the House of Representatives, and also at the ceiling of the hall, in the apertures for ventilation, through which air of the temperature of 77° Fahrenheit was issuing. As a controlling experiment, slips of the same paper were dipped in ozonized air and found to be colored of the same shade. Some of the paper was exposed to the external air at the laboratory. On the subsequent day, at 3*h*. 30*m*. p. m., the papers were examined. Those of the fan-room and of the external air at the laboratory gave a moderate but decided ozone reaction, which was greater in the case of the laboratory papers. The air leaving the hall gave a very slight evidence of ozone, merely enough to see that it was present. The ozone might have been removed from the air furnished by the fan either by the action of the hot coils, or by the

organic matters imparted to the air by the audience. If the heat had not destroyed it, the experiment gave proof that the fan furnished ozonized air to the hall. If the ozone was lost in the hall, it performed thereby efficient service in neutralizing the organic matter in the air which might be injurious. Further experiment was therefore required to ascertain whether the ozone was lost by the heat. Ozonized air, passing through a tube heated above the boiling point of water, is completely deprived of its ozone. On March 8, at 4 p. m., after the adjournment of Congress, slips of test-paper were placed in the main air-duct of the ventilating machinery of the House of Representatives, in the current, some of them immediately in front and the rest in rear of the heated coils. The fan was in action until March 11, and the papers were examined on March 15, at 10*h*. 30*m*. a. m. All of the papers exhibited the reaction of ozone, but it was less intense in the hot air. The closed shutters of a window had been opened inadvertently, suffering diffused daylight to fall upon the papers in the hot air, but the less intense tinge of the latter is not attributable so much to the light as to the heated coils which probably deprived the air of a certain portion of its ozone; the air, however, passes the coils too rapidly to lose much of its ozone by this means. The fact was thus established that *ozonized air* is furnished to the audience in the halls. Ozone could be readily generated in the air-duct by Dr. Delabrousse's plan, employing a spiral wire of platina, rendered incandescent by a galvanic battery; but such provision is unnecessary.

M. Saint Pierre (Comptes-Rendus, lviii 420, 1864) discovered a remarkable production of ozone by the action of certain kinds of ventilating apparatus. He found that test-paper, placed in the tuyere pipe of a blast furnace, gave evidence of ozone in a much stronger manner than when in the external air, and to show that the velocity of the current of air bringing greater quantities of air to the paper was not the cause of the reaction, he placed, at the same time, similar papers on the governor of a steam-engine in a saw-mill. From these and other experiments he concludes that the reaction arises from compressing the air. I have seen no reason for my experiments to suppose that ozone is generated by the action of the fan in the ventilating machinery of the Capitol.

Antozone.—The late researches of Schoenbein, Meissner, and others, have resulted in the discovery of another condition of oxygen, in which it has chemical properties antagonistic to those of ozone, and which has, in consequence, been called "*antozone*." As this body has probably an important bearing upon the hydration of dry air, it will be necessary to consider it in this report.

Schoenbein discovered that if a few drops of acetate of lead solution be added to diluted peroxide of hydrogen, the peroxide of lead ($Pb\,O_2$) is formed. The same reaction takes place if ozonized oil of turpentine be employed, or if ozonized oxygen be brought in contact with basic acetate of lead. In these experiments the peroxide of lead is produced by the oxidation of the protoxide of lead by ozone. When the peroxide of lead remains in contact with the peroxide of hydrogen, both are reduced, the result being water, protoxide of lead, and ordinary oxygen.

Schoenbein concluded, therefore, that the oxygen is in a different condition in the peroxides of lead and hydrogen. In the peroxide of lead it exists as ozone, ($Pb\,O\,\overset{-}{O}$.) and in other bodies which this chemist grouped together as "*ozonides*," such as peroxides of manganese and silver, permanganic and chromic acids, the oxygen is in the same condition; but in the peroxide of hydrogen the oxygen is contained in a different condition, ($H\,O,\,\overset{+}{O}$,) which he calls antozone. In peroxide of barium it is in the same condition, and all of such bodies Schoenbein terms "*antozonides*." In the conjunction of an ozonide with an antozonide, the different kinds of oxygen neutralize each other to form ordinary oxygen; we have then—

Air	$\overset{+}{O}\,\overset{-}{O}$
Ozone	$\overset{-}{O}$
Antozone	$\overset{+}{O}$
An ozonide	$M\,O,\,\overset{-}{O}$
An antozonide	$M\,O,\,\overset{+}{O}$

It was requisite for establishing the correctness of this hypothesis to produce antozone and to investigate its properties; but this body had already been prepared from peroxide of barium and oil of vitriol, and was supposed to be ozone. Schoenbein found that if this peroxide be projected in small quantities in cold monohydrated sulphuric acid, antozone escapes as a gas, mingled with ordinary oxygen, which latter, as he states, is formed from the antozone by the elevation of temperature during the reaction.

Antozone blues the iodide of potassium and starch like ozone, and has a smell like that gas, being more disagreeable. A distinguishing characteristic of antozone is

the formation of peroxide of hydrogen when it reacts with water, which ozone does not occasion. Among the different tests for these gases it is sufficient to note that of a slip of paper soaked with solution of sulphate of manganese, which is rendered brown in ozone from the formation of peroxide of manganese. In antozone not only does this reaction not take place, but a paper browned by ozone is bleached by antozone.

Meissner discovered that air or ordinary oxygen, electrified by Ruhmkorff's coil, well dried, and then passed into water or moist air, gave rise to a mist, or cloud, which was found to be due to the formation of antozone. The cloud could be caused to disappear by contact with drying substances such as oil of vitriol, chloride of calcium, &c., but would form again upon introducing the antozonized air into a moist atmosphere. By standing, the electrified air gradually lost its cloud-forming property, the water being deposited upon the sides of the vessel containing the gases. Meissner regards peroxide of hydrogen as a component of antozone with water; and clouds, or vesicular mist, as a physical aggregate of antozone and steam, in which the chemical attraction of the two is much weakened, if not destroyed. He attributes the gradual disappearance of the cloud to the return of the antozone (by combining with ozone) to its condition of ordinary oxygen. Von Babo attributes the mist to the formation of peroxide of hydrogen, and its disappearance to the precipitation or gradual decomposition of this peroxide. Meissner believes that tobacco, chimney, and gunpowder smoke, and that even the atmospheric clouds are due to antozone, which arises from all processes of oxidation.

While there is much to be learned respecting antozone, the cloud-forming attribute of this body is very interesting in connection with ventilation, and may serve to explain the difficulties which, according to some statements, have been found in communicating moisture to a current of air by means of steam. The escape of steam under favorable conditions is accompanied by electrical phenomena, and the production of ozone and antozone is thus possible. It is conceivable that an antozone cloud thus generated, and not having time while traversing the air-passages to deposit its vesicles of water, might be swept along into the apartment to be ventilated. According to Meissner, water condensing from oxygen or atmospheric air has always the form of vesicles, while in separating from other gases it assumes the condition of solid drops, or rain.

It might be more prudent, before adopting a method to supply to the air of the halls of legislation that amount of moisture in the winter time which is absolutely necessary to the health of the members, to institute a particular series of experiments upon the relations of antozone to the subject.

IV. RESUMÉ.

It follows from the experiments which have been given in detail in this report that—

1. The ventilation of the Capitol is abundant.
2. The air furnished is pure; and
3. It contains more ozone than the air of the
4. The source whence the air is taken is proper; but more cleanliness should be observed upon the terraces, &c., above the surface of which (if any alteration be deemed necessary) the air-shaft should rise not above three feet.
5. The principal defect of the air, and the cause of complaint, is in the hydration. This can and should be remedied.
6. The dust is dependent upon the condition of the streets of Washington; it rises at times above the summit of the dome of the Capitol. It might be removed by the method of hydrating the air in which sprays or films of water are used.
7. An extended research upon the proportion of carbonic acid in the atmosphere of America is needed. It has been performed for Europe; but in America, where the population is less and the vegetation is greater, scarcely anything has been done. Important scientific and practical results may be expected from such a research.

I am, gentlemen, very respectfully, your obedient servant,

CHARLES M. WETHERILL.

THOMAS U. WALTER,
Architect Capitol Extension.
Professor JOSEPH HENRY,
Secretary Smithsonian Institution.

CONCURRENT RESOLUTION authorizing appointment of select committee, passed in the Senate March 18, 1869.

Resolved, That a joint select committee be appointed, to consist of three members of the Senate and three members of the House of Representatives, to examine into the present condition of the Senate chamber and of the hall of the House of Representatives as regards lighting, heating, and ventilation, and their acoustic properties, and the defects and disadvantages existing in the same, and the cost, and the best method of providing remedies therefor; and that they have leave to report by bill or otherwise, and shall report also upon the probable cost thereof.

Concurred in by the House January 18, 1870.

Committee on the part of the Senate:

Mr. NYE, of Nevada.
Mr. ANTHONY, of Rhode Island.
Mr. STOCKTON, of New Jersey.

Committee on the part of the House:

Mr. JENCKES, of Rhode Island.
Mr. SANFORD, of New York.
Mr. SWANN, of Maryland.

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APPENDIX.